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COMMERCIAL PEAR GROWING

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Agricultural Research Service
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CONTENTS

This publication supersedes Farmers' Bulletin 1739, Pear Growing in the Pacific Coast States.

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COMMERCIAL PEAR GROWING

Agriculture Handbook 330

E R R A T U M

Page 28, column 2, line 4: Please change "approved" to disproved."

COMMERCIAL PEAR GROWING

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About 90 percent of the pear crop of the United States is produced in the three Pacific Coast States. Production there averages about 25 million bushels annually. Varieties of high quality and European origin (*Pyrus communis* L.) are grown exclusively. The major pear areas of the Pacific Coast States are characterized by dry summers with abundant sunshine. In the better orchards 30 to 35 tons of pears per acre are sometimes produced. The bacterial disease known as fire blight (*Erwinia amylovora* (Burrill) Winslow et al.), which makes it necessary to plant partly resistant varieties (generally of low quality) in most parts of the United States, can be controlled well enough on the Pacific coast to permit growing very choice varieties, even though they are susceptible.

CLIMATIC REQUIREMENTS OF PEARS

Although pears will tolerate a wide range of climatic conditions, their culture has been restricted mostly to areas that are particularly favorable for them. On the Pacific coast, pears are important commercially from south-central California up into British Columbia. The southern limit of commercial pear growing is determined by the prevalence of high winter temperatures. The commercial pear varieties grown on the Pacific coast require a considerable period of low temperatures (about 1,200 hours below 45° F.) during the winter so as to complete their dormant period and to start off vigorously in the spring. Therefore, pears are not adapted for commercial production in sections where winter temperatures are so mild that the trees do not complete this period before blossoming. More recently varieties have been developed that require less winter cold to break their dormancy. This characteristic makes them better adapted for areas where lack of winter chilling is a limiting factor.

Most pear varieties can stand fairly low winter temperatures without much injury. If the trees are fully dormant, temperatures as low as —15° F. usually do not cause serious injury. The wood and buds of pears are more subject to injury from low temperatures than apples under the same conditions. On the other hand, pears are slightly more resistant to low temperatures than peaches.

In all major pear areas of the Pacific coast, irrigation is depended on for moisture; consequently, rainfall does not determine the distribution of pear production. In other pear areas where natural rainfall is depended on for soil moisture, an average of at least 35 inches per year is desirable.

Air drainage and freedom from spring frosts are important in the location of a pear orchard. Pear trees bloom relatively early. If the dormant period has been completely broken during the winter, they normally bloom about 1 week before apples. The blossoms are about as easily damaged by spring frosts as are those of apples and peaches. Temperatures of 26° F. or lower will generally kill the open blossoms. Therefore, because of the earlier blooming season, the hazards from spring frosts are greater for pears than for apples. In some areas pear orchards are equipped with heaters to protect the trees during the blooming season, particularly where orchards are located on lowland where air drainage is not especially good. Because of the adaptation of pears to fairly heavy soils, orchards have frequently been located on lowland.

The most serious disease in pear production is fire blight. On the Pacific coast this disease is most serious in the interior valleys, particularly in California and southern Oregon, where spring and early-summer temperatures are likely to be high. In sections with cooler growing seasons, such as the coastal districts of California, the Willamette and Hood River Valleys of Oregon, and the Puget Sound section of Washington, pears are much less seriously affected by this disease.

[1] Retired.

TABLE 1.—*Average growing-season temperatures, by months, in commercially important pear areas of United States*

State and area	Station	Average temperatures in—						
		March	April	May	June	July	August	September
California:		°F.	°F.	°F.	°F.	°F.	°F.	°F.
Antelope Valley	Fairmont	52.1	57.0	63.9	72.3	80.9	79.8	73.0
Central	Auburn	51.2	56.1	62.4	71.4	77.0	76.0	69.2
	Marysville	54.3	59.4	64.8	72.8	77.8	76.2	71.9
	Sacramento	54.3	58.1	63.3	69.4	73.2	72.9	69.3
	Upper Lake	49.9	54.8	59.6	66.7	73.8	72.7	66.7
Central, coastal	San Jose	53.1	56.3	58.5	62.7	66.5	66.1	64.2
	Santa Rosa	51.2	54.4	57.6	63.0	65.2	64.4	63.8
Michigan, southwestern	Benton Harbor	34.7	47.1	57.9	68.1	72.7	71.3	64.0
New York:								
Hudson River Valley.	Poughkeepsie	37.3	49.5	60.7	69.6	74.6	72.4	64.6
Western	Rochester	32.3	45.1	56.7	66.9	71.6	69.7	62.4
Oregon:								
Hood River Valley	Hood River	43.3	49.9	56.1	61.6	67.4	66.6	59.5
Rogue River Valley	Medford	46.7	51.6	57.7	65.2	71.8	70.8	63.1
Washington:								
Wenatchee River Valley.	Wenatchee	42.8	51.5	58.8	66.2	73.2	71.6	61.6
Yakima River Valley.	Yakima	44.1	52.5	59.0	66.4	71.4	69.5	61.1

Fire blight is the major hazard in growing pears in many areas of the East and particularly the South. In such locations it is necessary to select varieties that are at least partially resistant to this disease.

The climate has a definite effect on the quality of certain varieties. The Bartlett, which is the most economically important pear variety, apparently reaches its highest dessert and best shipping and storage qualities where temperatures are high for the 2 months preceding harvest. When grown in hot sections, this variety ripens more slowly after harvest, remains in prime eating or canning condition longer, and has less tendency to break down at the core than when it is grown in cooler sections. The Bosc, another important variety, also appears to reach its highest dessert quality where temperatures are high. The Anjou, the second most important commercial variety, is well suited to cooler conditions. This variety is well adapted to the moderately warm valleys of the Northwest. Average temperatures at typical points in important pear areas are shown in table 1.

PEAR-GROWING AREAS

Most of the commercial pear production of the United States is restricted to areas where growing conditions are especially favorable. These areas are as follows: (1) Interior valleys of central California, including the smaller tributary valleys and adjacent slopes and foothills; (2) coastal sections of central California; (3) Rogue River Valley of southwestern Oregon; (4) Hood River Valley of north-central Oregon; (5) valleys of central Washington; (6) intermountain areas of Idaho, Utah, and Colorado; (7) central region; (8) northeastern region; and (9) southern region.

The pear acreage in the principal growing areas is given in tables 2–5. The pear-growing centers in California, Oregon, and Washington are shown in figures 1–3.

TABLE 2.—*Pear acreage in major producing counties of California and total for State, 1962* [1]

County	Bartlett pears			Other pears		
	Nonbearing trees	Bearing trees	Total	Nonbearing trees	Bearing trees	Total
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Lake	1,735	4,609	6,344	65	8	73
Sacramento	1,673	4,348	6,021	11	133	144
Santa Clara	950	3,989	4,939	31	1,348	1,379
Mendocino	2,170	2,127	4,297	30	29	59
Placer	621	3,222	3,843	9	153	162
El Dorado	524	2,596	3,120	1	207	208
Solano	617	2,294	2,911	0	42	42
Sonoma	638	1,633	2,271	0	6	6
Contra Costa	40	1,161	1,201	0	136	136
Other counties	3,786	4,250	8,036	373	904	1,277
Total	12,754	30,229	42,983	520	2,966	3,486

[1] Data from Calif. Dept. Agr. for California fruit and nut acreage in 1962.

TABLE 3.—*Acreage of principal pear varieties in California, 1962* [1]

Variety	Nonbearing trees	Bearing trees	Total
	Acres	*Acres*	*Acres*
Bartlett	12,754	30,229	42,983
Hardy	62	1,529	1,591
Comice	116	461	577
Winter Nelis	65	453	518
Bosc	2	270	272
Anjou	2	95	97
Other pears	273	158	431
Total	13,274	33,195	46,469

[1] Data from Calif. Dept. Agr. for California fruit and nut acreage in 1962.

Interior Valleys of Central California

Pear culture in the interior valleys of central California is mainly restricted to a few sections, but commercial orchards are scattered throughout almost the entire area. Approximately half the pear trees in California are growing in this area. The principal pear-producing sections here include (1) the bottom lands of the Sacramento River Valley, (2) the foothills east of this valley, (3) the valleys northwest of the lower Sacramento River Valley, and (4) the Clear Lake district of Lake County and the Ukiah district of Mendocino County. All are desirable for the production of the Bartlett variety.

Bottom Lands of Sacramento Valley

The bottom lands of the Sacramento Valley constitute one of the most important pear-growing sections of the Pacific slope. Between the cities of Sacramento and Isleton pear culture is the most important fruit industry. Practically all the pear trees in this section are near the river.

The soils devoted to pear culture are largely sedimentary and of recent origin, having been deposited over a layer of peat. In some places the overflow from the river has added to the the depth of the soil since the early orchards were established. Levees now prevent the river from overflowing. The dark soil is an open, friable, warm loam. The Bartlett, which is grown almost to the exclusion of other varieties, produces excellent fruit here both for dessert and for canning.

All orchards of this section are equipped for irrigation. Water from the river is easily and cheaply obtained by means of pumps beside the river and pipes through the river levees.

As in most other sections of California where pears are grown, the coldest weather brings frequent frosts but only occasional light freezes. A large part of the pear-producing section lies within the area where summers are moderately hot, although tempered to some extent by cool breezes from San Francisco Bay.

TABLE 4.—*Pear acreage in principal producing areas of Oregon and Washington, 1962* [1]

Variety	Hood River County, Oreg.		Jackson County, Oreg.		North-central Washington		Yakima Valley, Wash.	
	Nonbearing trees	Bearing trees	Nonbearing trees	Bearing trees	Nonbearing trees	Bearing trees	Nonbearing trees	Bearing trees
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Bartlett	2,218	2,243	820	4,020	2,330	1,623	6,390	6,120
Anjou	2,036	2,090	65	2,250	1,545	1,842	761	1,422
Bosc	108	159	167	1,786	1	9	100	150
Comice	45	35	576	842	0	4	.....	.....
Other pears	103	57	1,150	253	31	7	177	150
Total	4,510	4,584	2,778	9,151	3,907	3,485	7,428	7,842

[1] Oregon acreage calculated from data contained in Oreg. Fruit and Nut Survey, Spec. Rpt. 169, Oreg. State Univ., 1964. Washington acreage calculated from Wash. Tree Fruit Census, Wash. State Dept. Agr., Wash. Crop and Livestock Rptg. Serv., and Wash. Agr. Expt. Sta., 1963.

TABLE 5.—*Pear acreage in principal producing areas of Michigan and New York*

Variety	Michigan [1]		New York [2]	
	Southwestern	West-central	Hudson River Valley	Western
	Acres	*Acres*	*Acres*	*Acres*
Bartlett	5,600	1,700	825	1,920
Bosc	500	100	252	303
Clapps Favorite.	.....	.....	247	152
Seckel	.....	.....	487	132
Other pears	600	200	102	55

[1] 1959 Mich. Tree Census; 40 percent of total acreage under 8 years old.
[2] 1962 N.Y. Crop Rptg. Serv.; 36 percent of total acreage under 8 years old.

Pears in this section mature early. The first Bartlett shipments from the State usually originate here. The first shipments normally are made early in July, and the fruit moves to eastern markets for approximately 6 weeks. A large part of the late-harvested fruit is canned.

Foothills East of Sacramento Valley

In the foothills east of the Sacramento Valley about 7,000 acres of pears are in Placer and El Dorado Counties. The highest elevation of orchards in this section is about 3,500 feet. The Bartlett is by far the most important variety. The fruit reaches high dessert quality and ships well to market. On hillsides or where the soil is not deep, the fruit is usually smaller than that from orchards on the deep soils of the river bottom. Pears from lower elevations ripen about the same time as the river pears of the same varieties. The harvest in the higher orchards is considerably later; therefore, fruit from these orchards has an advantage in arriving on the market after peak shipments are past. The Bosc, Winter Nelis, and other winter pears are minor commercial varieties in this section, grown mainly as pollinizers for the Bartlett.

Most of the trees on the poorer soils in this section are not large, and the yield is not so heavy as on the deep bottom lands. Because of the late ripening of the fruit, its high shipping and dessert qualities, and excellent appearance, much of the output is shipped fresh, but some of it is canned. All the orchards are irrigated.

Much of the soil in this section is derived from the weathering of granite bedrock and is open, easily worked, fertile, and well drained, but it is low in organic matter. It is several feet deep in some places; in others it is shallow, and outcroppings of granite are common. In the Placerville-Camino district of El Dorado County, pears are planted mostly on Aiken clay loam, a residual soil from disintegrating schist rocks. It is red, friable, and of good depth and contains a moderate amount of organic matter. The summers are generally hot but somewhat shorter than along the Sacramento River or in the districts lower in the foothills.

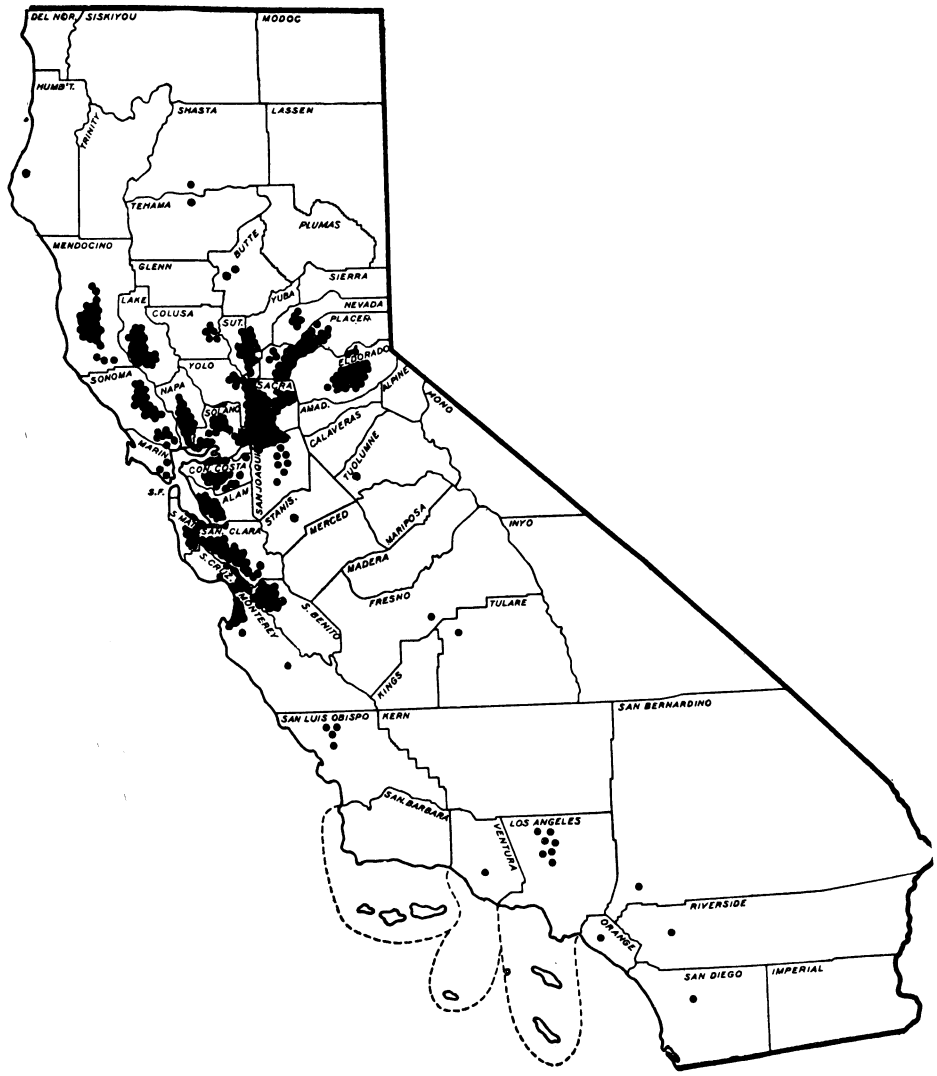

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FIGURE 1.—Distribution of pear growing in California; each dot represents 100 acres of pears.

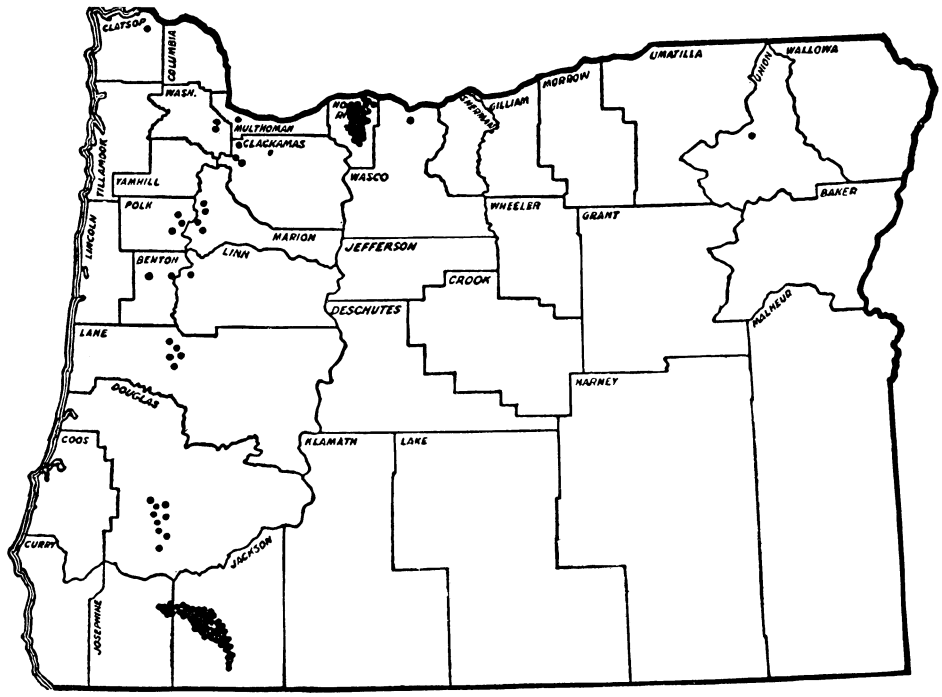

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FIGURE 2.—Distribution of pear growing in Oregon; each dot represents 100 acres of pears.

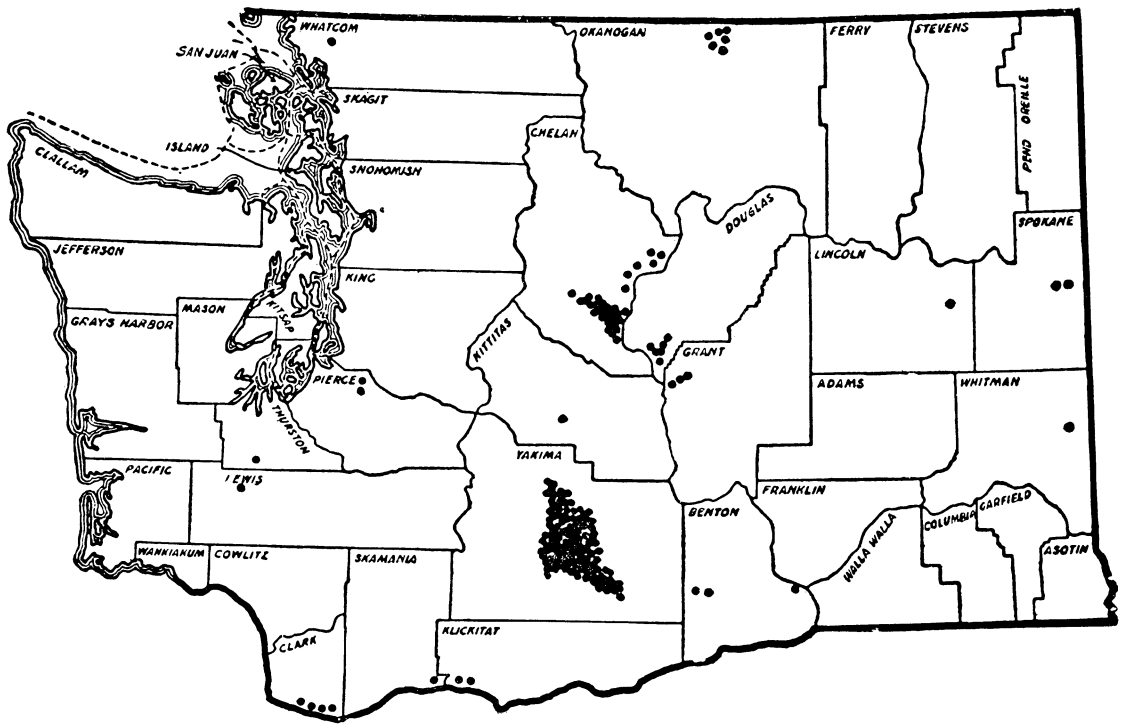

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FIGURE 3.—Distribution of pear growing in Washington; each dot represents 100 acres of pears.

Valleys Northwest of Lower Sacramento Valley

A third section of the interior valleys of central California includes the district near Fairfield and the Vaca Valley, which is northwest of the lower Sacramento River Valley; both are in Solano County. Around Fairfield the summer temperatures are more like those of the coastal section. Little water is available for irrigation. The Bartlett is the principal variety, and most of the fruit is shipped fresh.

In the Vaca Valley the summers are hot and advance rapidly. The soil is a very deep, fertile, friable loam, and the trees are thrifty, but on account of lack of moisture they do not grow rapidly and the tonnage of fruit produced is only moderate. The slow growth provides unfavorable conditions for fire blight development. Some of the pear orchards are old. There are but few new plantings, as most of the available orchardland in this valley has been planted.

Lake and Mendocino Counties

The fourth section of pear production in the interior valleys of central California includes the Clear Lake district around Kelseyville and Upper Lake, both in Lake County, and the Ukiah district in Mendocino County. In some places the soil is a deep and easily tilled loam, but generally it is a rather heavy black clay that gradually slopes to the level of the lake. It is very fertile but should be worked only at the proper time. All the orchards are irrigated. The water is obtained largely from wells.

The Bartlett is grown practically to the exclusion of other varieties (fig. 4). Trees grow well and bear regularly. The fruit is large, of good quality, and an attractive color. It ripens later than in the principal pear sections of the Sacramento Valley. Consequently, it reaches the market after the heavy shipments from

40034–P

FIGURE 4.—A 50-year-old Bartlett pear orchard with trees 40 feet apart in Lake County, Calif.

those sections have been sold. The fruit attains excellent shipping quality because of the high temperatures. Most of the crop is shipped fresh or sent to canneries. Lake County is the major fresh-shipment district in the State. Approximately one-half of its production moves into fresh-fruit channels.

Coastal Sections of Central California

The principal pear-growing sections between the Coast Ranges and the Pacific Ocean in California are the low coastal plains adjoining San Francisco Bay in Santa Clara, Alameda, and Contra Costa Counties; the Napa Valley in Napa County; and the Sonoma Valley in Sonoma County. The temperatures are much lower than in the interior valleys because of the ocean breezes. As a result, fire blight is less likely to develop and the fruit ripens later. The Bartlett is of less desirable quality for distant shipping than in sections where there are a few weeks of high temperatures before harvest.

This area is one of the oldest centers of commercial pear culture in California. A few of the orchards planted in the middle of the 19th century are still cultivated, though many of them, as well as younger acreages, have succumbed to the rapid encroachment of residential development.

More varieties are grown commercially in this area than in other parts of California. Bartlett is predominant, but there are substantial acreages of Hardy, Anjou, Bosc, Winter Nelis, and Comice. Bartlett is grown mostly for canning, but the other varieties are shipped fresh.

Many of the pear orchards near San Francisco Bay are at a low elevation. The soil is a dark moderately heavy clay, which is fertile but sticky when wet and hard when dry. Farther back from the bay and at higher elevations the soil becomes more loamy and open and is well adapted to the culture of other deciduous fruits and nuts. Occasional pear orchards have been planted on this more loamy land also, and they generally have good tree growth and production. Practically all the orchards of this section are irrigated. Santa Clara County ranked third in total pear acreage in California in 1962 with 6,000 acres.

Throughout this coastal area, as well as in the more southern sections of California, the Bartlett pear tends to lose its characteristic long shape. Under extreme conditions the radial diameter of the fruit almost equals its length, and the fruit is less desirable for canning. This condition constitutes a serious problem in coastal sections where the crop is largely used for canning. Tufts and Hansen (*52*)[2] have shown that length of fruit from the more southerly sections averages shortest in proportion to diameter; the ratios vary from about 1.2 to 1 in central California to about 1.5 to 1 in Yakima, Wash.

Rogue River Valley of Oregon

The principal pear plantings in western Oregon are in the Rogue River Valley of Jackson County, although there are limited plantings in the Umpqua and Willamette River Valleys. The Rogue River Valley area, lying west of the center of the State and almost touching the California line, has more than 10,000 acres of pears. It ranges from 1,874 feet above sea level at Ashland on the south to 935 feet at Grants Pass on the north and is almost entirely surrounded by mountains. Medford is the principal shipping point. Large plantings were made early in this century, although about half of the present acreage has been planted since water for irrigation was made available between 1917 and 1920.

Freezing temperatures occur throughout the Rogue River Valley in winter. Spring frosts are frequent, particularly on the floor of the valley, and orchards must be protected by heating, which is general and efficient. The lower slopes surrounding the valley seldom have damaging frosts during blossomtime because of good air drainage. The summers are hot, dry, and favorable for the ripening of pears. The rainfall from September to the following May totals 15 to 25 inches per year and is supplemented by irrigation during the dry season in all but a small percentage of the orchards.

Much of the soil in this section is a rather heavy adobe, and it is better suited to pears than other fruits. Although the soil is fertile, much of it is underlain by a stratum of hardpan at a depth varying from a few inches in some of the uplands to several feet in the bottom lands. In parts of the Rogue River Valley a high water table presents a serious problem, requiring community drainage efforts. On the deeper soils trees grow rapidly; on the shallower ones growth is rather slow. The slow-growing trees are less susceptible to fire blight, but production is also much less.

The Bartlett, Anjou, Bosc, and Comice are the varieties most extensively planted. The Bartlett is the most important, and recent

[2] Italic numbers in parentheses refer to Literature Cited, p. 46.

50057-P

FIGURE 5.—Typical Anjou pear orchard on adobe soil, Medford, Rogue River Valley, Oreg.

plantings have been largely of this variety, Anjou, and Comice. The Bartlett produced here has high dessert and canning qualities and ships well. The Bosc blights badly here, but it bears heavily and the fruit is of good size, quality, and appearance. The Anjou is popular because of its excellent size, appearance, and dessert and storage qualities. It is the most blight resistant of the varieties extensively grown (fig. 5).

In the Umpqua and Willamette River Valleys pears are grown commercially, but they are not among the most important fruits. Summer temperatures are lower than in the Rogue River Valley and not warm enough for the best development of most pear varieties. Because of the lower temperatures there is almost no loss from blight. Winter injury has at times been serious in the Willamette River Valley, causing the loss of many orchards.

Hood River Valley of Oregon

The Hood River Valley, about 120 miles from the coast and at the extreme northern boundary of Oregon, is an important pear-growing area. The Bartlett and Anjou are the principal varieties grown (table 4). The Bartlett is used mainly for canning, with some fresh-fruit shipment.

The soils of this area vary considerably in depth and texture, but not sufficiently to restrict the planting to given soil types. Pear orchards are scattered throughout the fruit-growing part of the valley. Most of the surface soils are sandy or silty loam, very open, and in many places rather shallow. Water passes through these soils rapidly. The subsoils are composed of about the same materials as the upper soils in many places. Some of the subsoils are very open, permitting good or

sometimes excessive drainage; others are so compact that downward movement of water through them is slow.

The rainfall during the summer is light, and practically all orchards are irrigated. With the very open and well-drained soils in one locality and compact subsoils in another, careful observation and caution are necessary in adopting a successful irrigation program. Although the roots of pear trees can stand excessive soil moisture better than the roots of many other fruit trees, they will not thrive in waterlogged soils. Therefore, where a hard substratum is too near the surface, care in drainage is necessary to prevent an accumulation of seepage water from higher levels.

As the soil has a high sand and silt content and the surface layer suited to root growth is shallow in some places, the humus content needs to be increased and maintained. Cover crops, either cultivated plants or native vegetation, are grown for this purpose in most orchards.

Winter injury constitutes a greater hazard to pear production in this area than in most of the other important pear areas of the Pacific coast. Winters are generally mild, but occasional severe cold weather when the trees are not thoroughly hardened has resulted in serious damage, particularly to young trees. Fire blight has not been serious in the Hood River Valley.

Valleys of Central Washington

Two irrigated sections, one the Yakima River Valley and the other along the Columbia and Wenatchee Rivers centering around Wenatchee, are the most important pear-producing areas of Washington. Pear orchards are scattered throughout these large fruit-growing belts. In the older orchards pears and apples were often interplanted. In both sections the soil is generally deep, fertile, and well suited to pear growing. As the rainfall is very sparse and occurs during the winter, all orchards are irrigated. Fire blight, although troublesome in some years, is not so severe as in the Rogue River Valley of Oregon and the interior-valley sections of California. For acreages and varieties of pears grown, see table 4.

In both the Yakima and Wenatchee sections the Bartlett attains good size, shape, and quality for canning. The fruit reaches the extreme length in proportion to width in these northern sections, a shape very popular for canning. With abundant cold-storage facilities in the area, much of the Bartlett crop is held in cold storage and sent to canneries when they want it. Some of it is placed on the fresh-fruit market after the California shipments are over.

Intermountain Areas of Idaho, Utah, and Colorado

Pears are a relatively minor crop in Idaho, Utah, and Colorado. Production is mainly restricted to the semiarid valleys and foothills where other deciduous fruits are grown. In Idaho, pear orchards (about 500 acres, mostly Bartlett) are scattered throughout the southwestern part of the State in the same general areas where apples are produced. In Utah, most of the pears (about 1,200 acres, mostly Bartlett) are produced in Utah County about 75 miles south of Salt Lake City in the vicinity of Provo. Orchards are located on canyon deltas above the floor of the valley. Commercial pear production in Colorado is limited entirely to the western slope in Mesa and Delta Counties.

Pears in the intermountain areas require irrigation. Climate and growing conditions are similar to those in the lower Yakima Valley of Washington. Bartlett and Anjou are the principal varieties grown.

Central Region

Michigan, the leading pear-producing State of the central region, ranks fourth in production, exceeded only by California, Oregon, and Washington. The pear industry of this State centers in three southwestern counties—Berrien, Van Buren, and Allegan—located along the eastern shore of Lake Michigan. The moderating effect of the lake reduces the dangers of spring frost, and the relatively cool weather during the early growing season aids in the control of fire blight. Bartlett is the principal variety.

Pear production in Illinois is scattered through several counties in the southern third of the State but centers in Marion County. Other principal pear-producing States in the central region include Ohio and Indiana. In the former State commercial production is centered in the counties bordering on the southern shore of Lake Erie. Pear acreage in Indiana is widely scattered, but most of it is centered in Posey and Gibson Counties in the extreme southwestern corner of the State.

Northeastern Region

New England climate is generally regarded as too severe for pear production, except a relatively small acreage in the Connecticut River Valley. New York, however, produces substantial quantities of pears. The production areas of this State are centered in western New York and the Hudson River Valley. The lead-

ing pear-producing counties of western New York are located on the southern shore of Lake Ontario. Climate and soil conditions in this area are similar to those in southwestern Michigan. Pear acreages in the Hudson River Valley are located south of Albany and centered in Columbia, Orange, Ulster, and Dutchess Counties. In New York the Bartlett constitutes nearly 70 percent of the pear acreage.

Pear production in Pennsylvania is widely scattered and the crop is used largely to supply local demands. Chester and Lancaster Counties and the southeastern part of the State are the most important areas.

Southern Region

With few exceptions high-quality European-type pears cannot be successfully grown in the South because of susceptibility to fire blight. Pears of the oriental type are far more tolerant, but their fruit quality is low and they are best suited for cooking and preserving. Several varieties have been developed (see p. 23) with improved quality and fire blight resistance. Most of these are hybrids between *Pyrus communis* and oriental species, but some have been derived entirely from *P. communis* varieties. Also, varieties have been developed that require less winter cold to break dormancy and are consequently better adapted to the warmer areas of the South. Such pear-breeding programs are making it possible to produce better quality pears throughout the Southern States.

Relatively few areas in the South produce pears commercially. Most production is primarily for home consumption, with a limited outlet for local markets. Pears are grown in widely scattered areas throughout the Southern States. If blight-resistant varieties are planted in well-drained soil on a site with good air drainage, pears can be satisfactorily produced in many areas of this region.

Kieffer is perhaps the most widely planted pear in the South. It is moderately resistant to fire blight but is relatively low in quality. Maxine and Waite are superior in quality to Kieffer and somewhat more resistant to fire blight. They are well adapted to southern conditions. Baldwin and Orient have a lower chilling requirement than other varieties and can be grown in the lower South, where mild winter temperatures are insufficient to break dormancy.

SITES AND SOILS FOR PEAR ORCHARDS

From the standpoint of air drainage for frost protection, the slopes of rolling lands are preferable for pears; but for the purpose of crop diversification, these places are often planted to fruits that blossom earlier than pears, such as apricots, almonds, plums, and peaches, and are therefore more susceptible to frost injury at blossomtime. Consequently, pears are frequently planted at the lower sites, where artificial frost-prevention practices are sometimes necessary. Because of better air drainage, trees located on sloping land are less susceptible to fire blight and the fruit is less likely to develop serious russeting.

The best soil for pears is deep, medium textured, well drained, fertile, and easily worked. Although pears will thrive best on such a soil, they will do reasonably well where the soil has a high water table, is poorly aerated, or is too heavy in texture for most other deciduous fruits. Pear trees seem to grow well on the heavy soil of the Santa Clara Valley, Calif., and the heavy adobe in the Medford, Oreg., district. If grown on tolerant rootstock, they can withstand unfavorable soil-moisture conditions. Trees growing behind the levee of the Sacramento River have each winter a water table within 2 feet of the surface and occasionally have stood in water for many days. This is not an ideal situation, but does illustrate the tolerance of the pear toward unfavorable conditions.

ROOTSTOCKS FOR PEARS

Since pear varieties, like other improved fruits, cannot be reproduced from seed, one must plant trees that have been propagated on seedling roots by either budding or grafting. These seedling roots are commonly known as rootstocks. Perhaps no other phase of pear culture is more important than the proper choice of a rootstock on which to grow the different varieties of pears. Extensive studies have been made to determine the most suitable rootstocks for propagating pear trees. It has long been known that rootstocks vary greatly in susceptibility to fire blight and other diseases. Also, the degree of tree vigor and of hard end and cork spot of fruit is affected by the kind of rootstock used (table 6). Rootstocks assumed added significance when it was shown that the incidence of pear decline in the Western United States depended on the rootstock used (p. 44).

TABLE 6.—*Important characteristics of pear rootstocks*

Rootstock and source	Vigor rating	Incidence of black end on scion fruit	Pear decline resistance	Soil adaptability	Tendency to produce suckers	Fire blight resistance
Domestic French (*Pyrus communis* L., usually Bartlett or Winter Nelis seedlings).	Vigorous top; strong, well-anchored roots.	None or very rare.	Very high	Tolerates wide range of moisture and soil texture.	Great	Low.
Imported French (*P. communis* L., seedlings).	do	do	High	do	do	Do.
Old Home (variety of *P. communis* L., propagated vegetatively).	do	do	Very high	do	do	Very high.
Japanese pear (*P. serotina* Rehd. (*P. pyrifolia* (Burm.) seedlings (oriental)).	Vigorous top when young; older trees moderately weak; weak root system.	Most varieties highly susceptible.	Low	Highly sensitive to both excessive and deficient soil moisture.	Little	Moderate.
P. ussuriensis Maxim. (seedlings (oriental)).	Variable vigor; moderately weak root system.	Moderately susceptible.	Moderate	Sensitive to both excessive and deficient soil moisture.	do	High.
P. calleryana Decne. (oriental).	Very vigorous top; strong, well-anchored roots; lacks winter hardiness.	Rare	High to very high.	Tolerates wide range of moisture and soil texture.	do	Do.
P. betulaefolia Bunge (seedlings (oriental)).	Very vigorous top; inferior fruit quality on some varieties.	Moderately susceptible.	High	do	do	Variable.
Quince (*Cydonia oblonga* Mill., propagated vegetatively).	Slow-growing top; weakly anchored roots.	Rare	Moderate to high.	Trees need support (staking) in wet soils.	Great	Do.

Until about World War I, most pear trees were propagated on French seedlings. The seeds were obtained from cider mills of continental Europe and were derived from native trees of *Pyrus communis*. During and immediately after World War I, French seeds were not generally available and nurserymen used oriental seedlings (*P. serotina* Rehd. and *P. ussuriensis* Maxim.) almost exclusively. The greater resistance of these stocks to fire blight was an added incentive in bringing about their widespread use. These stocks proved highly desirable from the standpoint of the nurseryman. They were easy to propagate and made a thrifty tree in the nursery row. Under good soil and moisture conditions, trees propagated on these stocks grew well in the orchard. However, fruit from these trees frequently exhibited black end, rendering it virtually worthless for marketing purposes. Because of this serious disorder, many orchards propagated on these stocks were eliminated.

About 1925, most propagators returned to the use of French seedlings. In most cases seeds were obtained from western canneries and came from open-pollinated Bartlett, although Winter Nelis seeds were used to some extent. Thus, about 1925 marks the beginning of the use of domestic seedlings of *P. communis*, generally referred to as domestic French. Stocks derived from this source, although susceptible to fire blight, have proved

satisfactory under a wide variety of conditions, and since 1930 have been the predominant stock used in the Pacific Coast States.

Other stocks used to a limited extent include *P. calleryana* Decne. and *P. betulaefolia* Bunge. Both of these stocks of oriental origin were introduced in 1918 by F. C. Reimer of the Oregon Agricultural Experiment Station. *P. calleryana* produces a vigorous tree and is fire blight resistant although it is not winter hardy in the more northern pear-growing areas. Varieties grown on this stock do not develop black end. This is the preferred stock in the southern pear-growing areas. *P. betulaefolia* is generally regarded as an undesirable rootstock, because it lacks hardiness and is susceptible to blight and black end.

Extensive projects were conducted by the Oregon Agricultural Experiment Station to develop a satisfactory pear stock resistant to fire blight. Of many varieties and types tested, Old Home generally proved the most satisfactory. It is highly blight resistant and is believed to be a pure form of *P. communis*. It was selected by F. C. Reimer and has been used as a trunk stock to a limited degree in some of the pear districts of Oregon and California. The general practice has been to use Old Home as a trunk stock by budding it on to French seedling roots in the nursery. After 2 or 3 years in the orchard, framework branches are grafted to the desired variety. The result is a blight-resistant framework but with blight-susceptible roots. Successful attempts have been made to obtain roots on Old Home cuttings (*21*). Trees developed by this means possess blight resistance in both the roots and trunk.

With the advent of pear decline in the Western United States, there has been considerable interest in using Old Home as a rootstock. Observations have indicated that trees in which Old Home trunks had scion rooted were more resistant to pear decline than those where the Old Home trunk had not rooted.

In recent years there has been less emphasis on blight-resistant trunk and rootstocks. With improved methods of blight control on the scion variety, there is less danger of serious losses from fire blight entering the framework and roots. In addition, the added cost of providing a tree with a resistant trunk or roots is also a factor.

In certain areas of the Pacific Coast States, particularly Santa Clara County, Calif., several pear orchards have been planted on quince roots (*Cydonia oblonga* Mill.). Various types of quince have been selected, but Angers and Provence are most generally used. Most varieties when grafted on quince do not make a satisfactory union, and it is necessary to use an intermediate stock, usually Hardy or Old Home. Bartlett trees on quince roots are rather dwarfed, attaining about half the size of standard trees. These trees are early bearing, and because of their small stature are more economical to prune, spray, and harvest. However, trees on quince roots are shallow rooted, more weakly anchored, and generally require more exacting care.

SOIL MANAGEMENT AND COVER CROPS

Cultivation

In most commercial pear orchards some form of cultivation is generally practiced. The usual reasons for cultivation are as follows: To remove noxious weeds and weed competition; to facilitate subsequent orchard operations such as irrigation, spraying, brush removal, and harvesting; to incorporate cover crops and manures; to prepare the soil as a seedbed for cover crops; and to conserve moisture.

The most common practice is to disk under the cover crop, either volunteer or planted, that has grown during the fall, winter, and spring. In irrigated areas, the cultivation is performed in advance of the first irrigation. During the remainder of the season the frequency of cultivation will depend on the method of irrigation and the amount of water available. In central Washington where irrigation water is plentiful, no further cultivation is generally practiced until after harvest. The cover growth occurring during the summer is usually mowed or "floated down" in late summer to facilitate harvest operations. In the Medford district of Oregon and certain areas of California, cultivation is often performed between each irrigation, and thus the soil is kept relatively free of vegetation during the growing season.

Cover Crops

A good cover crop helps to maintain organic matter and to prevent erosion; it improves the physical texture of the soil and aids in water penetration. During the fall, winter, and early spring the growing of some cover crops to be incorporated in the soil is an excellent practice. The cover may be a volunteer crop of weeds or grass, or preferably one that has been planted.

The choice of a cover crop should be determined by such environmental factors as soil, water supply, and temperature. Among those most commonly used are annual legumes (yellow sweetclover, common vetch, and purple vetch), mustards, and cereals (rye, barley, and oats). These are generally planted from the middle of September to the middle of October in order to be established before cold weather. In irrigated areas an irrigation is required after seeding to induce germination.

Permanent Sod

In some sections pear orchards have been successfully handled in permanent sod without cultivation. In the central Washington districts fescuegrass is the preferred cover for this purpose. Permanent sod is particularly suited where the sprinkler method of irrigation is used. Sod reduces runoff and increases water percolation. Most covers require mowing at least twice a year, and it is necessary to have sufficient water available for both trees and cover crops.

Legume covers such as alfalfa are not preferred in most pear sections. The control of insects is made more difficult, because legumes are good host plants for the tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)), various species of mites, and other insects harmful to pears. Furthermore, the added nitrogen obtained from legumes makes it more difficult to control the desired level of this element. Excessive vigor increases the difficulty in controlling fire blight. Also, in the northern fruit areas a high nitrogen level in the fall increases the susceptibility of the trees to low temperatures, which may occur in late fall or early winter.

FERTILIZATION

In many pear areas nitrogen is the only element needed for proper nutrition of pear trees. The amount required to maintain satisfactory growth and production will vary with the soil type and method of culture. Mature orchards usually require from 75 to 150 pounds of actual nitrogen per acre. It should be applied in either late fall or early spring.

All fertilizers containing nitrogen affect the acidity of the soil. Since slightly acid soils are preferable for pears, all alkaline soils or soils irrigated with hard water, which makes the soil alkaline, should be fertilized with ammonium sulfate. Soils already acid should be fertilized with materials having the least effect on soil pH. These materials include ammonium nitrate, urea, and anhydrous ammonia.

In some western soils, particularly if slightly alkaline, zinc is not available in sufficient amounts to meet the needs of the trees. Zinc deficiency causes the condition known as "little leaf" or "rosette." Leaves are small, very narrow, light colored, and tend to develop in small clusters or "rosettes." Affected leaves also lack the normal green, particularly between the veins. This interveinal chlorosis of leaves on limbs and branches exhibiting little leaf or rosette is positive evidence of zinc deficiency. Zinc deficiency in an orchard can be largely corrected by spraying the trees with zinc sulfate solution just before the buds open in the spring. Zinc applied to the soil is generally unavailable to the trees, because it is largely tied up or "fixed" in the few inches of surface soil.

Zinc deficiency of pears is most common in central Washington, although it has been observed in some orchards in nearly all the major pear areas of the Western States. In California zinc deficiency is most likely to occur in the delta area of the Sacramento River.

In some orchards boron deficiency may also be a problem, particularly in north-central Washington. Boron deficiency may be expressed in several forms. The most common malformity is cork development in the fruit. If the deficiency becomes acute early in the season, a rough scabby or russeted skin will develop, and the fruit will generally crack without showing noticeable cork (fig. 6). If the boron shortage occurs relatively late in the season, well-defined pitting will develop (fig. 7). Associated with these pits are corky areas extending rather deeply into the flesh of the fruit. A diagnosis of the deficiency is con-

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FIGURE 6.—Young pear fruits exhibiting early-season symptoms of boron deficiency.

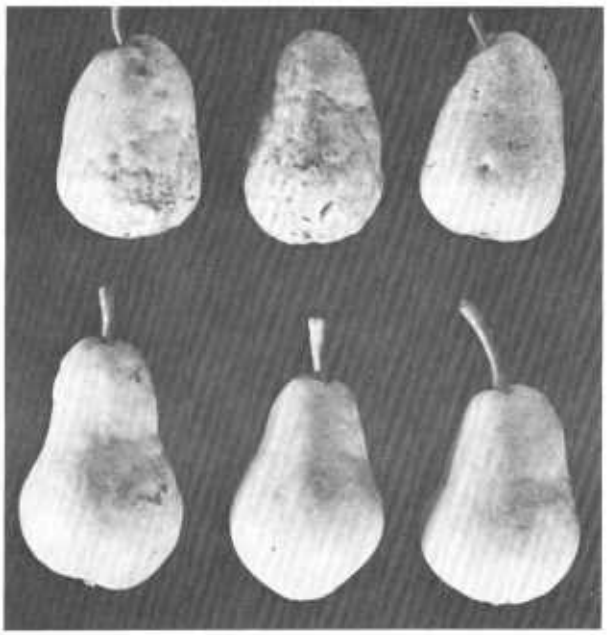

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FIGURE 7.—Pitting of Bartlett pears caused by boron deficiency (top row); normal fruits (below).

BN-29826

FIGURE 8.—Bartlett pear blossoms exhibiting typical symptoms of blossom blast. Note persistence of dead blossoms.

firmed by boron analysis. Mature fruits should contain 10 p.p.m. or more boron and young fruits over 20 p.p.m.

"Blossom blast" (*3*) is another form of boron deficiency that sometimes occurs in Washington orchards. Typical symptoms are shown in figure 8. Generally the blossoms wilt and die, but the leaves remain normal. The withered blossoms fail to abscisss and frequently persist until the following year. With the more severe forms, leaves also die and the limb may or may not put out new buds within a few weeks after the blast occurs. If it fails to do so, the branch dies before the next season. Blossom blast within an orchard is random in its distribution; rarely more than 10 to 20 percent of the trees are affected. Usually the disorder is confined to one or two leaders on the tree, whereas the remaining limbs are normal. Fruit set is greatly reduced on affected limbs.

The general characteristics and conditions associated with blossom blast suggest that the deficiency is incipient or temporary in nature. The following evidence tends to support this premise (*3*): Tissues of affected trees have a relatively low boron content early in the season followed by a level of boron equal to that in trees which do not develop the trouble; fruits borne on affected limbs fail to develop deficiency symptoms in the form of fruit pitting later in the season; soil applications of boron fail to correct the disorder effectively; and blossom blast occurs chiefly on heavy soils in seasons unfavorable for early root growth.

It has been shown that the boron requirement of pear trees suffering from all types of boron deficiency can be effectively supplied in the form of boron sprays, preferably applied in late summer or early fall. Early spring applications may fail to become effective before blossom blast is initiated. Soil applications are generally effective in preventing fruit symptoms, but have no advantage over a yearly spray application.

When soil pH values become greater than 7, deficiencies of iron and manganese may develop. The most common of these high pH problems is iron deficiency, or lime-induced chlorosis. It occurs when alkaline water is used for irrigation or when water containing alkaline salts rises to the surface in a seepage area. Leaves lacking iron are yellow, with a fine network of green veins. In severe cases the leaf dies around the edges. Although chlorosis is sometimes difficult to correct, the most effective means is soil injection of an iron chelate solution. Iron chelate sprays applied early in the growing season are generally less effective than soil injections.

Manganese deficiency is rather common in several of the pear-growing areas of the Pacific Coast States. Symptoms are found on the leaves only, and the older leaves are affected more than the young ones. The chlorosis is yellow or golden in contrast to creamy white of zinc deficiency. Leaf size is not affected as in the case of zinc. The chlorosis pattern is interveinal, i.e., the leaf tissue adjacent to the major veins remains green, but the tissue between the veins turns yellow. The diagnosis is verified by leaf analysis. Values less than 25 p.p.m. of manganese are low and less than 15 p.p.m. indicate acute deficiency.

Manganese deficiency is easily corrected with manganese sulfate sprays, but there are few, if any, instances where such a treatment is necessary. The use of ammonium sulfate as a nitrogen fertilizer provides all the control necessary by making the soil sufficiently acid to release enough manganese to meet the requirement of the trees.

Only a few instances of potassium deficiency have been recorded throughout the pear-growing areas of the Pacific Coast States. Potassium diminishes with depth, and where land has been leveled to facilitate irrigation, some deficiency may occur. Potassium deficiency is also prevalent in a few foothill orchards of California, where the soil is unusually light and shallow. In certain areas of New York and Michigan potassium deficiency frequently occurs, particularly when young pear plantings are set in old orchard sites.

An acute shortage of this element results in marginal leaf scorch, which appears first on older leaves of spurs and shoots. Milder symptoms involve a rolling of the leaf blade upward and inward, giving the leaf a "cigar-shaped" appearance. When potassium is deficient, fruit size is reduced and maturity is accelerated. The deficiency can be positively diagnosed by leaf analysis and can be corrected by liberal applications of potassium salts to the soil or the use of a mixed fertilizer containing adequate quantities of this element.

Magnesium deficiency is rather common in parts of the South and may be a factor in certain areas of New York and Michigan. The symptoms of magnesium deficiency are yellowing of the leaf at the margins and browning of the margins as the leaf ages. Some varieties show distinct interveinal chlorosis and interveinal browning. The leaves are generally small, and in severe cases partial defoliation occurs before harvest. Symptoms rarely develop before midsummer and are not prominent until late summer or fall. They are usually much more pronounced on spur leaves, though the deficiency can frequently be observed on the basal leaves of terminal shoots. In severe cases premature defoliation occurs and fruit size is reduced. Dolomitic limestone is generally applied as a corrective measure.

IRRIGATION

Supplying water to the trees in irrigated areas is one of the most important operations in successful pear growing. If the orchard becomes so dry that the rate of fruit growth is reduced during the growing season, final size of the fruit and total tonnage will be reduced in proportion to the length and severity of the water shortage. On the other hand, use of excessive water may lead to difficulty. Poorly drained soils may become waterlogged and injure roots. Because water must be pumped and is expensive in many pear districts, it should not be wasted.

Three methods of applying water are used in pear orchards. In California on fairly level land of medium or heavier texture, the flooding or basin method is largely used. Small dikes are erected as necessary to enclose an area of approximately level land. They should be small enough so that water can be applied rapidly from the available supply. These basins are then filled with water sufficient to restore soil moisture to the desired depth. Generally 6 to 8 acre-inches will be supplied per irrigation. This method wets all the soil uniformly.

On moderately sloping land the rill or furrow method is generally used. Four or five furrows, equally spaced in the center between each tree row, are opened. Water from a head ditch or pipeline is run into these furrows at such a rate that it will be taken into the soil within the length of the furrow. Furrows must have only a moderate slope—generally 4 to 6 inches per 100 feet—to avoid erosion and to obtain even, moderately uniform infiltration. In light-textured soils often the whole root zone will not be wet from furrows. In the tree row, particularly, an area of dry soil remains. Also, with furrows it is difficult to supply a uniform quantity of water along the length of the furrow. Frequently excess water may accumulate at the lower end of the furrow, or sometimes insufficient water may reach the lower end. Skill and care are essential for uniform application of water from furrows.

A third method of application is with sprin-

klers. Light-weight aluminum pipe, with rapid coupling devices, is used in many pear orchards, especially where the soil is fairly steep or so open that water enters it rapidly. By sprinkling, all the soil is wet and response of the trees has been very good, particularly on sites where uniform distribution of water by furrows or basins is difficult. Equipment for sprinkler irrigation is expensive, but improved water distribution and tree response are justifying its use in many orchards.

The amount of water required by pear trees will vary with the temperature and humidity and with the size and leaf area of the trees. Only a small amount of water is used before the bloom season, since there is little foliage on the trees. Use of water increases as the foliage develops and as the days become hotter and generally drier.

In the interior valleys of the Pacific Coast States, vigorous mature pear trees will use from 5 to 6 acre-inches of water per month in July and August and a little less in June and September. Since some water is lost by evaporation and from other causes when irrigating, about 7 acre-inches per month may need to be applied in July and August. On deep soils of good water-holding capacity, this amount can be applied in one irrigation, and irrigating monthly will be satisfactory. On shallow or coarse-textured soils, more frequent and lighter watering should be practiced.

PRUNING

Pruning is necessary to obtain satisfactory yields of good-quality fruit. The growth conditions and the various characteristics of different varieties all determine the type and degree of pruning in a given situation. In general, the greater the amount of pruning the larger the fruit and the less the total yield. Both canners and shippers prefer fruit 2⅜ inches in diameter and larger. To produce fruit of adequate size and quality, moderate pruning is required, but extreme pruning should be avoided because of its adverse effect on yield.

Pruning Young Trees

The pruning of young trees is intended to develop tree structure. By skillfully selecting certain branches for the framework and by removing others, the pruner builds the foundation for long-lived trees that is strong enough to carry heavy crops. With young trees, developing structure is the first concern; producing fruit is secondary. Thus, pruning young trees may more properly be referred to as training. During the training process the aim should be to develop a sturdy tree capable of producing large crops of quality fruit.

At the time of planting, young trees should be cut back to 24 to 30 inches from the ground to balance the loss of roots removed in digging the trees from the nursery and also to form a relatively low head, which is desirable in developing a profitable tree. During the dormant period after the first growing season (fig. 9, *A*), three branches should be selected and headed to a length of 24 to 30 inches in order to force secondary branches. All others should be removed. The selected branches may emanate at about the same point on the trunk, or they may be selected around the trunk at a distance of 6 to 8 inches apart. The angles of the framework branches should be as wide as possible for added strength, but this feature is not so important as with apples. Pear limbs rarely break under the stress of a heavy load.

At the second dormant pruning (fig. 9, *B*), the secondary framework branches should be selected. Generally each of the three branches forming the original framework will give rise to several shoots, from which four to six secondary scaffolds are selected. All other vigorous growth is removed. Each of these branches should be headed at the point where a third set of branches is desired.

Beginning with the third dormant pruning (fig. 9, *C*) and continuing until the framework is complete, each of the four to six secondary branches selected at the second pruning is headed at the point where the next whorl of branches is desired. The other shoots are thinned out and left unheaded. Further heading is usually unnecessary. If the trees have grown well, the framework should be established. Until the tree comes into bearing, only small branches should be moderately thinned. The lighter the pruning at this point the larger the tree and the sooner it will fruit (fig. 10, *A*).

Pruning Bearing Trees

After a tree begins to bear fruit, pruning is necessary to maintain a balance between fruit production and vegetative growth. Although fruit color is not a factor, branches and shoots

FIGURE 9.—Bartlett trees before (left) and after (right) pruning: *A*, 1 year old; *B*, 2 years old; *C*, 3 years old.

should be thinned out sufficiently to allow adequate sunlight in order to maintain vigor throughout the bearing area of the tree. Excessive heading back of shoots is likely to result in too much vegetative growth. Both heading and spacing are usually required to maintain a proper balance. If sufficient wood for spur replacement is obtained and if trees are not pruned so severely as to limit the crop, it makes little difference whether the desired results are obtained by thinning, heading, or a combination of both. A well-pruned Bartlett tree is shown in figure 10, *B*. Some moderate heading of vigorous shoots was performed, but thinning and spacing of excessive shoot growth constituted the bulk of the pruning.

Anjou, with its characteristically light set of fruit and consequent large leaf area per fruit, frequently produces fruit larger than that preferred by the trade. The ideal way to produce smaller fruit would be to increase the number of fruits per tree. However, since the pruning of Anjou generally increases the percentage of blossoms setting fruit more than enough to compensate for the reduction in number of flower buds incident to pruning, many growers rely on rather heavy pruning. Although satisfactory in some seasons, such heavy pruning stimulates the rate of fruit growth so much that with a moderate crop the final fruit is often larger than desired. Furthermore, with repeated heavy pruning, the yield per tree in some years may be considerably less than that of trees with annual light pruning.

Experimental evidence indicates that over a period of years annual light pruning will produce as great a total yield and with vigorous trees a slightly greater yield than annual heavy pruning. The advantages of the lighter pruning include less cork spot (see p. 45) where cork is a problem, more desirable fruit size, and the opportunity for greater yield per tree.

In pruning pear trees, particularly Anjou, emphasis should be placed on the removal of limbs with spurs over 4 or 5 years old. To renew these limbs, an excess of new water sprouts should be left each year. These should be thinned out when they are 2 years old, leaving those that have or, if still needed, those that will set fruit spurs in the coming years. The remainder are removed. These renewal shoots should be left until they have produced one or two crops and then replaced with new or younger fruiting shoots. By a rotation system of this type old spurs are not permitted to develop. Where this system has been rigidly followed, the cost of pruning is not excessive and fruit set and yield have been very satisfactory.

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FIGURE 10.—Bartlett trees after pruning: *A*, 5 years old; *B*, mature.

POLLINATION

Numerous pollination experiments show that Bartlett and Anjou are virtually self-sterile. They also show that these varieties may be highly self-fruitful in the West because of the production of parthenocarpic fruits (without seed). However, cross-pollination generally aids in the setting of fruit by all important pear varieties under some, if not all, conditions.

In the Western States good crops of Bartlett and Anjou are harvested where no provision is made for cross-pollination. The degree of self-fruitfulness of these varieties depends on the season and growth status of the tree. If temperatures are relatively cool during the bloom period and immediately following, fruit set in solid blocks of these varieties will be much lower relatively than where cross-pollination is provided. Likewise, the lower the vigor the more likely fruit set will be adversely affected where there is no provision for cross-pollination.

Even where vigor and weather conditions are optimum, cross-pollination generally results in a greater fruit set. This may not be an advantage if the increased set is not needed for an adequate crop, because such a situation would necessitate the removal of surplus fruit in order to obtain adequate size. However, in many fruit areas, particularly in the Northwest, cross-pollination will pay large dividends by increasing yields in more years than not. Also, there are areas in California where Bartlett will benefit in most years with cross-pollination, even though there are many successful orchards of this variety grown in solid blocks.

Most of the fruit in these orchards is seedless and generally has the desirable feature of being longer in proportion to its diameter. The overall size of seedless pears may not be so great as seeded fruit (cross-pollinated), though the experimental information on this point is inconclusive. Seedless pears are more prone to harvest drop than those with seed,

but this can be prevented through the use of hormone sprays (see p. 21).

Griggs and Iwakiri (*16*) in a comprehensive study determined whether a seedless Bartlett was the result of stimulative parthenocarpy, caused by the stimulus of self-pollination, or whether fruit set was due to vegetative parthenocarpy, which occurs without any pollination. During four seasons of experiments these workers found that stimulative parthenocarpy failed to result in a significantly higher set than when pollen was not involved (vegetative parthenocarpy).

Additional evidence was obtained by caging trees with tight mosquito netting, either with or without a colony of bees enclosed. These tests showed that bees working the blossoms failed to increase the self-fruitfulness of the Bartlett pear. It may be concluded, therefore, that bees are of doubtful value in Bartlett orchards unless other varieties are interplanted or are within bee-flight range so that cross-pollination is possible. In the East, Bartlett and most other varieties cannot be depended on to set fruit without cross-pollination.

In providing for cross-pollination one should consider the commercial value of the pollinizer and when it blooms in relation to the variety to be pollinated. All important pear varieties that produce viable pollen are compatible. The Waite and Magness varieties are pollen sterile and obviously will not function as pollinizers. The pollinizer and the main variety must bloom concurrently or their blossoming period must overlap. If sufficient chilling to break the rest period occurs during the dormant season, most pear varieties overlap reasonably well.

Bartlett has a relatively long chilling requirement, whereas Winter Nelis requires much less chilling to break dormancy. Thus, when mild winters occur in the Sacramento Valley, Winter Nelis bloom may be too early to adequately pollinate the later opening Bartlett blossoms. In such instances Hardy is a preferred pollinizer, since this variety has a chilling requirement similar to that of Bartlett and is likely to bloom at about the same time whether the winter is mild or cold.

Varieties grown in southern regions may vary considerably in time of bloom. For example, Baldwin and Orient, because of their short chilling requirement, may bloom too early to pollinate Maxine or Waite.

In colder areas the chilling requirement of a variety is of no consequence, because the winters are always cold enough to adequately satisfy all varieties. In the Western States both Bartlett and Anjou are important varieties and are considered good pollinizers for each other. In Michigan and New York, Bosc is frequently used as a pollinizer for Bartlett.

Often a grower is interested in planting only one variety and would like to have as few pollinizers as possible. In most areas every fourth tree in every fourth row is adequate. With this pattern only 6 percent of the trees are pollinizers, and two diagonal spaces represent the maximum distances from the main variety to a pollinizer. When pollinizers are provided, it is necessary to have an adequate supply of bees to transfer pollen from one variety to another. One strong colony for every 2 acres is generally adequate.

The best time to place bees in the orchard is when the first blossoms open. Pear blossoms are not particularly attractive to bees, and placing them in the orchard earlier encourages the bees to go elsewhere. It is not necessary to distribute the hives singly throughout the orchard. Placing them in groups of 5 to 10 in a warm protected place not only promotes optimum activity but also facilitates handling.

FRUIT SET

Even under optimum conditions of pruning, cross-pollination, and general culture, Anjou pears with heavy bloom in the Pacific Coast States frequently fail to set a capacity crop of fruit. Various types of chemical sprays have been tested to increase fruit set on this variety. Batjer and Thompson (*5*) working in central Washington found that boron sprays (50 to 100 p.p.m. of boron) applied during the bloom period appreciably increased the set of Anjou under certain conditions. In speculating on the mechanism involved, these workers concluded that a probable explanation was the correction of an incipient or temporary deficiency of boron.

In later work Degman and Batjer (*10*) found that a 7.5 p.p.m. concentration spray of 2,4,5-trichlorophenoxypropionic acid (2,4,5–TP) when applied to Anjou immediately prior to or after harvest generally resulted in a marked increase in fruit set the following year. During years when unsprayed check trees set a full crop, very little benefit was obtained from the spray treatment, but in years when the checks set a light crop, 2,4,5–TP spray resulted in a moderate increase in set and yield.

In several districts of central Washington the use of 2,4,5–TP has become standard commercial practice on Anjou. Bartlett is rather sensitive to 2,4,5–TP, and if the treatment is used on this variety, the concentration should not exceed 3 to 4 p.p.m.

With the advent of naphthaleneacetic acid (NAA) to prevent harvest drop on Bartlett, several experienced growers reported that these sprays also increased fruit set. Although experimental evidence is lacking, extensive observations indicate that this may be true. After the discovery that 2,4,5–TP increased fruit set, it would seem logical that NAA sprays, though less effective, could act in a similar manner.

FRUIT THINNING

Many varieties of pears set heavy crops that do not develop to good marketable size, particularly Winter Nelis, Bosc, and Bartlett. If medium to large fruit is desired, part of the crop from such trees should be thinned in order to have a larger leaf area per fruit. In California, thinning of Bartlett is seldom necessary.

Many pear varieties, such as Bartlett, Hardy, and Bosc, tend to set the fruit in clusters, often three to five fruits on a single spur. If the set of fruit on the tree as a whole is excessive, these clusters should be reduced to one or two fruits each by removing the smaller ones. On the other hand, if the set of fruit on the tree as a whole is not excessive, fruit in these clusters will reach satisfactory size and quality without thinning.

It is impossible to lay down hard-and-fast rules for the thinning of pears. The number of fruits a tree will develop to good marketable size will vary with its vigor and growing conditions. Experiments indicate that with nearly all varieties from 30 to 40 good leaves per fruit are essential for the manufacture of materials that produce fruit. However, these leaves need not be directly adjacent to the fruit. With extremely heavy sets of fruit, thinning to reduce the amount of fruit in proportion to the leaf system is essential if fruit of best size and quality is to be obtained. Since fruit that is small at thinning time tends to remain so, it should be removed at that time.

As the natural drop is usually over about 6 weeks after bloom, the earlier the thinning is done after this the greater is the effect on improving the size of the remaining fruit. At 50 days from full bloom, fruit size of Bartlett is about 10 percent of harvest size and at 70 days growth has increased to only 20 percent of the ultimate size. Thus the size of the remaining fruit can be favorably affected but to a less degree with relatively late thinning.

In some areas, particularly California, growers rely solely on selective picking to supply the necessary thinning. When pears of 2⅜ inches in diameter and larger are removed in the first picking, the fruit remaining on the tree will likely increase in volume at a daily rate of about 2 percent. Thus, about 1 week is required to obtain an increase of ⅛-inch diameter for the remaining fruit. Bartlett pears, however, should not be permitted to remain too long on the trees for size increase, since both shipping and canning quality may be seriously impaired (see section on harvesting and handling).

HORMONE SPRAYS TO PREVENT FRUIT DROP

Dropping of fruit before or during harvest causes considerable loss in some years. This is especially true in solid blocks of Bartlett rendered seedless for lack of cross-pollination. This loss can be greatly reduced by the use of hormone sprays on most varieties where drop is a serious problem.

Such sprays are now used generally by commercial pear growers. NAA has been effective for this purpose when used at a strength of 5 to 10 p.p.m. In most sections of California NAA is usually incorporated in a mite spray, which is applied 2 to 7 days before harvest. The spray becomes effective within 2 or 3 days and generally controls drop for 3 to 5 weeks.

Another hormone, 2,4-dichlorophenoxyacetic acid (2,4–D), may also be used to prevent drop. From 10 to 14 days may be required for 2,4–D to become effective, but the effect lasts considerably longer than NAA. Pears are sensitive to 2,4–D and injury may result if more than 3 to 5 p.p.m. are used. Formulations containing the ester or high volatile types of 2,4–D should be avoided.

When hormone sprays are used to prevent the natural drop of fruit, it is important that the fruit be harvested at the proper stage of maturity; it should not be allowed to remain on the tree too long. Overripe pears, particularly Bartlett, break down soon after harvest.

PRINCIPAL PEAR VARIETIES

Pear varieties may be classified into two broad groups—the French types, or those of European origin (*Pyrus communis* L.), and the hybrid types, which originated as crosses between European varieties and oriental species. In general, the European varieties are much higher in quality but more susceptible to fire blight. Because of this, the hybrid types are better adapted to southern conditions.

French Types—*Pyrus communis* Origin

Anjou

Anjou (fig. 11), a large green pear of French origin, has been grown in the Pacific Coast States over a long period, but most plantings have been made since 1920. It is the most important winter pear and second only to Bartlett in total production. Anjou is grown mainly in Washington and Oregon, with limited plantings in California.

The fruit is attractive and high in dessert quality. It keeps well in storage until March or April or slightly longer in sealed polyethylene liners, and may be marketed over a long period. The entire commercial crop is marketed as fresh fruit. The tree is vigorous and grows large. This variety is more resistant to fire blight than other large high-quality varieties. It is a consistent bearer but a slow producer. Rather heavy and detailed pruning improves fruit set on older trees.

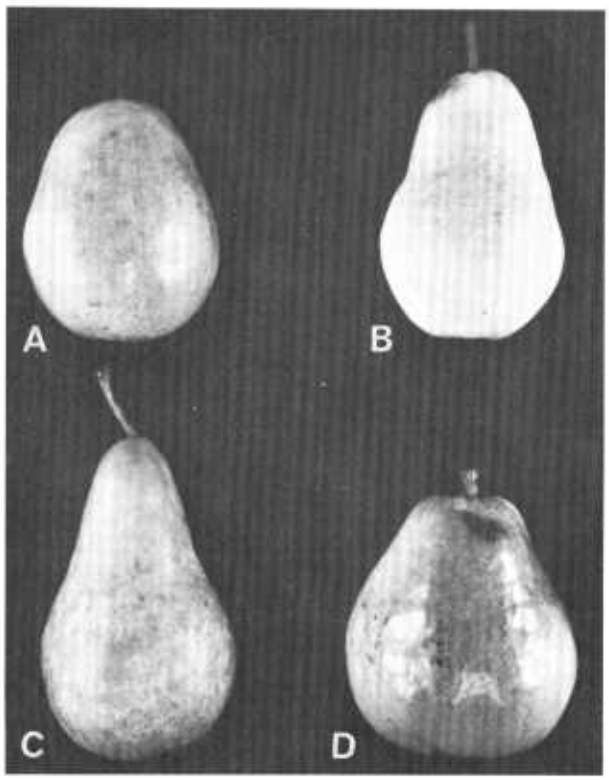

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FIGURE 11.—Important pear varieties of European origin: *A*, Anjou; *B*, Bartlett; *C*, Bosc; *D*, Comice.

Bartlett

Bartlett (fig. 11) is grown on almost three-fourths of the pear acreage of the Western States. It is also an important commercial variety in Michigan and New York. Nearly two-thirds of the crop is canned. About one-third is sold as fresh fruit and is shipped to all parts of the United States. Small quantities are dried.

The trees are adapted to a wide geographical range and to a great diversity of soil and climatic conditions. They are prolific, bear regularly, and endure neglect, abuse, and uncongenial surroundings surprisingly well. These characteristics, combined with the quality and uses of the fruit, make Bartlett a remarkable variety.

When well grown, Bartlett is generally considered the standard of excellence by which other pears for fresh-fruit shipment are measured. It is the only variety in the West to be used for all purposes. In flavor and texture it is unsurpassed among the major commercial varieties. It is the first of these varieties to ripen. The picking season ranges from early July in the valleys of central California to late August or early September in other areas where this variety is grown.

The fruit may be held successfully up to 2½ months in conventional cold storage. It is normally off the fresh-fruit markets by the middle of October. Bartlett is best both in dessert and in storage and handling qualities when grown under fairly hot summer conditions. In the coastal sections of all the Pacific Coast States where summers are very cool, the fruit does not keep so well after harvest as in the hotter interior sections and usually is less rich in flavor. Fruit from these coastal sections is generally canned or used locally, as the carrying quality is not sufficiently good to allow shipment to distant markets.

Bosc

Bosc (fig. 11) is grown on about 2,000 acres, mainly in the Rogue River Valley of Oregon where the fruit is excellent. It is also an important variety in New York and Michigan.

The fruit grows to good size. The yellow skin, which is almost covered with a brown russet, is particularly attractive. It is a fall and early-winter fruit, reaching prime market condition in October and November. The tree bears rather early and produces heavy crops.

The tree, particularly while young, is difficult to shape by pruning. The branches produce vigorous new shoots from their terminals. These remain rather slender for a considerable time and branch but little, so that the tree remains open and often becomes ungainly and willowy by the spreading of the slender branches. Special attention is required to maintain a tree of desirable shape.

Trees of this variety are attacked by fire blight about as seriously as those of any other commercial variety. The fruit may be seriously affected by stony pit virus. The tree is less tolerant of poor soil drainage than many other varieties.

Comice

In the Santa Clara Valley of California and the Rogue River Valley of southern Oregon, Comice (fig. 11) is grown on nearly 2,000 acres. This tree is open and rather easily managed by pruning, but it is not so consistent in bearing habits as many other varieties, often setting very light crops.

The fruit is large, light greenish yellow, and of excellent dessert quality. In flavor it is among the very best of the pears. It keeps well if handled carefully and can be held in cold storage into January. However, it is one of the most easily bruised of the commercial varieties. The skin is tender and easily punctured, and even light bruises at picking time will result in darkened areas on the fruit. It is also readily injured by the rubbing of the leaves and branches. In recent years much of the crop has been marketed for gift packages and other channels where special handling can be given.

Hardy

Hardy is grown on about 1,500 acres, mainly near San Francisco Bay and in the Santa Clara and San Juan Valleys of California. The tree grows well, is a heavy bearer, and appears to be more resistant to fire blight than Bartlett.

It is rather easily handled by pruning, because it is not inclined to branch freely and remains open. Much of the new growth takes place at the terminals of fruiting branches or where branches are headed back or removed. Numerous large fruiting spurs instead of shoots develop along the fruiting branches and remain vigorous and productive for many years. The wood unites well with quince and is frequently budded on quince roots and then topworked to other varieties.

The fruit is of good size and shape, keeps and handles fairly well in storage, and attains an attractive flavor. It ripens soon after Bartlett and before Bosc and Anjou. It was a favorite for export prior to World War II, but now it is largely used in canned fruit mixes and baby foods.

Maxine

Maxine is well adapted to most areas of the South. It ripens in mid-September between Orient and Kieffer. The fruit is large, attractive in shape, and yellow when ripe. The flesh is average in firmness and moderately gritty, with flavor and quality above the average of hybrid pears. It is suitable for eating fresh and rated high as a canned product. The tree is vigorous, productive, and generally rather tolerant to fire blight.

Seckel

Seckel is more tolerant to fire blight than any of the principal varieties of the French type. Because of this characteristic it can be grown successfully under a wide variety of climatic conditions, including areas throughout the South. The fruit is small but of excellent flavor and quality. The tree comes into bearing late, but is usually very productive as a mature tree. This variety is of limited commercial value because of its small fruit, but it is highly prized for home use and local markets.

Hybrid Types—*Pyrus communis* Crossed With Oriental Species

Baldwin

Baldwin (fig. 12) because of its low cold requirement to break dormancy is an excellent variety for the lower South. If planted in the middle and upper South, however, it may bloom too early, and consequently spring frosts are likely to cause loss of crop. The fruit is almost round and golden yellow when ripe. Its fresh and processed qualities are considered good for a hybrid variety.

Kieffer

Kieffer (fig. 12) is perhaps the most widely planted pear in the Southern and lower Midwestern States. It is grown chiefly for home consumption.

The trees are vigorous and well adapted to a wide geographical range and to a great di-

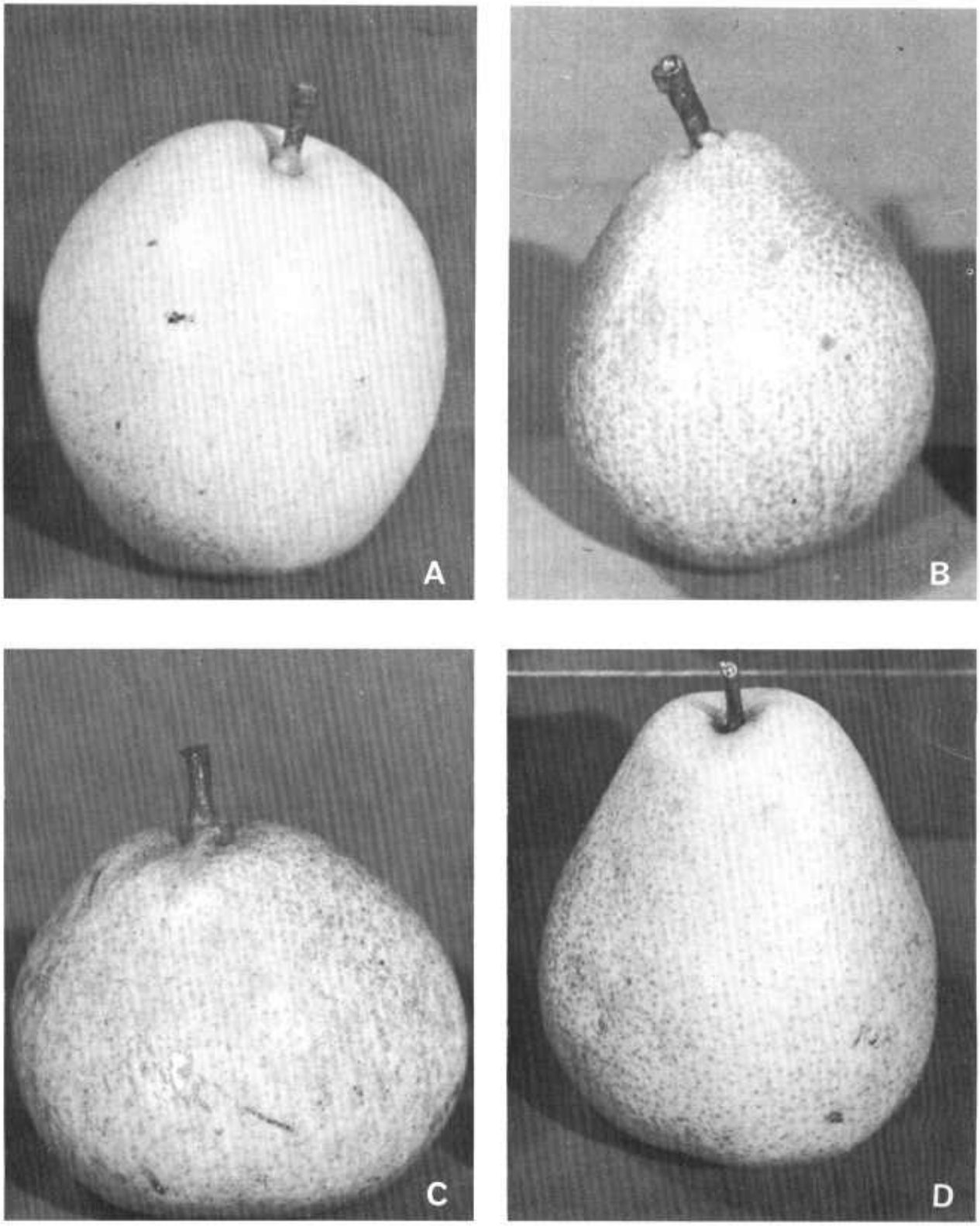

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FIGURE 12.—Hybrid-type varieties adapted for southern areas: *A*, Baldwin; *B*, Kieffer; *C*, Orient; *D*, Waite.

versity of soil and climatic conditions. Its moderate fire blight resistance makes it possible to grow this variety in areas where many European varieties will succumb to this disease. Kieffer blossoms relatively early and is unfruitful with its own pollen. It therefore requires the presence of another variety blossoming at about the same time in order to set heavy crops of fruit.

Kieffer matures in late September or October, depending on the area. The fruit is medium to large, developing an attractive color when ripened properly. Its flesh is firm, moderately juicy, and gritty. Although the dessert quality is low, the canned product is usually good.

Orient

Orient (fig. 12) ripens in late August or early September. It blooms several days earlier than Kieffer and has outstanding resistance to fire blight.

The fruit is large, nearly round, and greenish, with juicy flesh that is firm and only moderately gritty. It is only fair as a fresh fruit, but the canned product is attractive in appearance and of good quality. The tree is vigorous and productive, with a willowy type of growth becoming almost weeping under a full crop of fruit. Orient is recommended for planting throughout the Southern States.

Waite

This variety (fig. 12) possesses a high degree of fire blight resistance and is well adapted to the middle and upper South. Waite was introduced by the U.S. Department of Agriculture in 1938. Its fruit resembles that of Bartlett in size and shape. The quality is fair to good. The seasons of Waite and Kieffer are the same.

PROMISING NEW VARIETIES

El Dorado

El Dorado (fig. 13) originated about 1925 as a chance seedling near Placerville, Calif. During the past few years considerable interest has developed in this variety, and several hundred acres have been planted in Oregon and Washington.

El Dorado is a winter-type pear of European origin, which fits well into the late marketing season. It is harvested just after Anjou and usually with Comice. The fruit is distinctly pyriform in shape, often resembling the Bartlett variety, clear skinned, and with a moderately long, flexible stem. The fruit is as large as that of Bartlett, and the flesh is essentially free of stone cells. The skin becomes an attractive pale yellow when the fruit is ripened.

In limited storage tests El Dorado has not developed scald or core breakdown. The fruit has stored well at 30° F. until April and May. Taste tests indicate that it has excellent quality.

The fruit is moderately free of blemishes and russeting and resists mechanical injury as well as that of Bartlett and Anjou. Shelf life is as long as that of Anjou and longer than Comice or Packham's Triumph. The fruit also resists pressure and friction bruising.

This variety has not been widely tested and should be planted only on a trial basis until more is known of its performance.

Packham's Triumph

Packham's Triumph (fig. 13) originated in New South Wales, Australia, and was introduced there commercially about 1900. It is a European-type pear. It was introduced into the United States about 1945. Several commercial plantings have been made in Oregon and Washington.

The fruit is large and similar to that of Bartlett in shape, except that the surface is likely to be rough and irregular, particularly on the larger fruit. The skin is lemon yellow when ripe. The flesh is fine textured and juicy, with a particularly rich and pleasing flavor. Packham's Triumph matures about 30 days after Bartlett and keeps well in cold storage for 4 to 5 months. The tree is upright, vigorous, and a good producer, but highly susceptible to fire blight.

Varieties Recently Introduced

The Agricultural Research Service of the U.S. Department of Agriculture recently introduced Magness, Moonglow, and Dawn, which were developed at Beltsville, Md., from 8,000 seedlings of the pear-breeding program. They were all derived from European varieties. The first two are fire blight resistant, and all three are considered good to excellent in quality. These varieties have not been widely

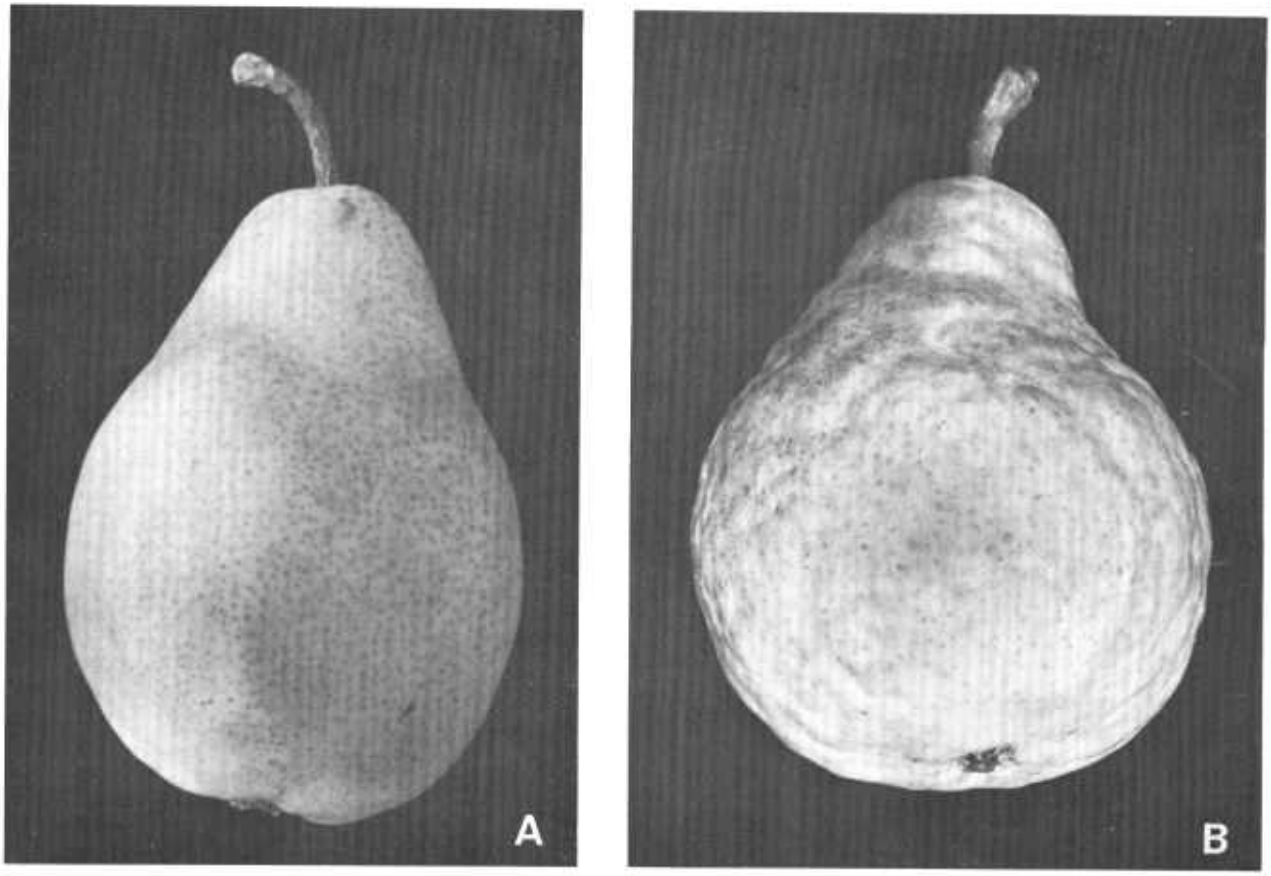

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FIGURE 13.—Promising new pear varieties currently being evaluated: *A*, El Dorado; *B*, Packham's Triumph.

tested and should therefore be planted on a trial basis until more is known of their performance.

The picking maturity of Magness is 10 to 14 days later than that of Bartlett. The fruit is lightly covered with russet, medium size, and generally oval. The flesh is soft, very juicy, and almost free of grit cells. The mature fruit has a sweet flavor and is highly aromatic. When in prime condition it rates with the highest quality pears. It can be held in storage up to 3 months and ripens with good quality. The tree is very vigorous and spreading; it possesses a high degree of fire blight resistance. Magness is pollen sterile.

Moonglow is mature for picking about 7 days before Bartlett. The fruit is attractive, has rather soft flesh, is moderately juicy, and is nearly free of grit cells. The flavor is mild and subacid. The fruit is considered good for processing as well as fresh consumption. The tree is vigorous, upright in habit, and resistant to fire blight. Both Moonglow and Magness are recommended for trial, especially in areas where fire blight is a major problem.

Dawn matures about 10 days earlier than Bartlett. The fruit is pyriform, generally resembling Bartlett in shape. It will average slightly smaller than Bartlett. The fruit is very good in quality and is aromatic, sweet, and very juicy. It is almost entirely free of grit cells. The tree is only moderately vigorous and perhaps is no more resistant to fire blight than Bartlett. It is recommended for trial as a relatively early variety in areas where Bartlett can be grown satisfactorily.

HARVESTING AND HANDLING

To attain their highest quality, pears must be harvested before they are ripe. However, if picked when too immature, they are undersized and often shrivel in storage. They lack sweetness and flavor and are susceptible to storage scald. On the other hand, if picked too late, the fruit ripens quickly and has a short storage potential. It often is gritty in texture, lacks juiciness, and is subject to core breakdown.

Picking Maturity

Flesh firmness is the most satisfactory single index of pear maturity. The optimum picking pressure will vary somewhat under different growing conditions, but the pressure test is a valuable aid in determining the proper time for picking in any district.

Flesh firmness is determined with a Magness-Taylor pressure tester, which indicates the amount of pressure in pounds required to force a rounded plunger five-sixteenths inch in diameter into the pared flesh of the pear to a depth of five-sixteenths inch. The measurement should be made at two or three locations on the circumference of the fruit. Russeted and blushed areas should be avoided, because readings from them are usually higher than from other parts of the fruit.

In cool districts or cool seasons and with ample moisture, pears tend to be softer and greener than those grown in hotter districts, especially if there is a shortage of water. Pears grown in hot weather tend to be yellow and remain firm in texture.

Magness and others (*34*) reported that in the hot districts of central California, especially when accompanied by a shortage of water, Bartlett pears were a distinct yellow when of proper picking maturity and tested as high as 23 pounds' pressure. Pears from the cooler growing districts, with sufficient soil moisture, were greener and softer when mature enough to harvest, and high quality was obtained only when the fruit was picked with pressure tests under 20 pounds; pears testing between 17 and 19 pounds generally have the best quality.

Abnormally cool growing seasons may also affect the harvest date. Hansen (*17*) found that premature ripening of Bartlett pears in the Hood River area occurred in districts with comparatively cool growing seasons and only in years when temperatures were below average. The several weeks prior to harvest were more critical than those earlier in the growing season. The earliest indication of premature ripening in the orchard appears as pink coloration near the calyx. Affected fruits soften and break down in the core area and fail to ripen normally. When the symptom first appears on some of the fruits, the crop should be harvested, and even though firmer than recommended, the fruits may be handled normally and will usually ripen to fair quality.

Recommendations for proper pressure-test readings for different pear varieties are listed in table 7.

There are other valuable indices of maturity in addition to pressure tests. Color, corking of the lenticels, and general finish aid in determining proper picking time. Lenticels of immature pears are white, and as cork cells develop, they become brown and shallow. The brown in the lenticels is a good indication that the fruit will ripen without shriveling. Color between the lenticels also becomes lighter green than at the lenticels. A characteristic waxiness of the skin and the rounding out of the fruit are also guides in determining the optimum picking maturity.

Of various physiological tests for maturity, the soluble solids test is the most indicative of quality. A close correlation exists between flavor and soluble solids. In California the Bartlett Pear Commodity Committee has established a combination firmness-soluble solids test in its maturity regulations. A pressure test of 21 pounds, reported to the nearest half pound, is the maximum allowable, and then only if the soluble solids are at least 10 per-

TABLE 7.—*Flesh-firmness recommendations for harvesting pear varieties*

Variety	Firmness[1]		
	Maximum	Optimum	Minimum
	Pounds	*Pounds*	*Pounds*
Anjou	15	13	10–11
Bartlett	19	17	[2]15
Bosc	16	13	11
Comice	13	11	9
Hardy	11	10	9
Kieffer	15	13–14	12
Seckel	18	16	14
Winter Nelis	15	12.5	11

[1] Magness-Taylor pressure tester with 5/16-inch-diameter plunger.

[2] See p. 28 for modification.

cent.[3] General picking may start at 20 pounds irrespective of solids content.

Bartlett is the variety commercially canned almost exclusively in the Pacific Coast States. Pears for canning are usually picked at a lower pressure-test reading than are those for fresh consumption. Canners usually specify the range of sizes and the grade, and the trees are selectively picked three or four times at 7- or 10-day intervals to meet requirements.

In a study of maturity and handling of Bartlett pears for canning in the Pacific Northwest, Ezell and Diehl (*12*) concluded that fruit picked at a pressure test of 15 to 17 pounds was the most desirable. These pressures ordinarily permitted the harvesting of maximum tonnage, and the fruit was best suited for the storage and ripening procedures involved with processing. Pears picked at higher pressures darkened more when cut and continued to darken during preparation for canning. At pressure tests of 14 pounds and lower, the pears tended to break down at the core before they had reached the desired softness for canning. This tendency developed rather rapidly below 14 pounds' pressure.

Climatic conditions modify these figures for optimum maturity. Pears may soften very slowly during a hot season or in a hot production area, although they may change from green to yellowish and soluble solids may increase. In some California districts with hot, dry growing seasons, a desirable maturity may be reached when the flesh firmness is 21 pounds or slightly higher. In such cases maturity indices, such as color, finish, and soluble solids, must be considered.

Packing

Pears destined for immediate consumption on the fresh market may be packed and shipped without precooling or without being held in cold storage previous to shipping. It is usually desirable that this fruit arrive on the market in a condition that will quickly reach the eating-ripe stage.

For pears that are not to be shipped immediately after harvest, the best practice is to pack them as they come from the orchard and cool to a core temperature of 29° to 31° F. to arrest ripening. However, packing operations often cannot keep pace with harvest, and accumulated pears should be placed immediately in cold storage and packed as promptly as is feasible.

The belief among many pear shippers that handling pears while cold results in skin blemishes, variously known as "finger prints," "abrasions," "scald," and similar descriptive terms, has been approved. Smith (*51*) reported that refrigeration did not make Bartlett and Anjou fruits more susceptible to surface abrasions, but that resistance of the skin to injuries declined with advancing age in storage. Bartlett pears promptly cooled and held at a core temperature of 31° F. for up to 4 weeks were not more susceptible to surface blemishes after this interval in storage. Thus, with prompt and adequate refrigeration, the packing season for Bartlett pears may be safely extended for 2 or 3 weeks and that of Anjou pears for 6 to 7 weeks after the fruit has been picked. Fruit so handled may be washed and packed without previous warming.

Most of the pear tonnage for the fresh market is packed in standard wooden pear boxes, which have inside measurements of 18 inches long, 11½ inches wide, and 8½ inches deep. The packed box weighs from 53 to 55 pounds and the net weight of the fruit is from 47 to 49 pounds. Lug boxes of wood or fiberboard with approximate inside dimensions of 13½ by 16 by 6½ inches are frequently used for large pears, and recently the use of tray-packed boxes has increased. The tray packs are identical with those used for apples and consist of paper-pulp trays in fiberboard boxes.

Several new types of packs, which may eventually accommodate a large percentage of the pear tonnage, are still in the developmental stage. Prepackaged trays overwrapped with shrinkable films and packed in fiberboard boxes have been tested experimentally, and limited numbers of commercial shipments have been made (*13*). Some shippers report good results with pears wrapped and packed in standard fiberboard boxes, eliminating the cost of trays. The height of these boxes is slightly reduced to accommodate a net weight of 45 pounds. A "tight fill" fiberboard box is also being used commercially, chiefly for Bartlett pears in California. It is a labor-saving pack in which the boxes are filled from the ends of belts and tightly packed by vibration. Box lids, fixed by staples or other means, produce a compressed pack, which prevents movement of the pears in handling and transit.

Since 1952, when sealed polyethylene film liners were first used commercially for pear storage, nearly all pears in the Western States destined for the fresh market are packed in "poly liners." In the liners an atmosphere develops in which carbon dioxide accumulates and oxygen diminishes. Both conditions contribute to an extension of storage life if the

[3] L. L. Claypool. Personal communication. Univ. Calif., Davis.

resultant levels are in the proper range. The respiration rate is lowered and the fruit maintains greater firmness and has a lower content of soluble pectin. Moisture loss from the pears is held to a low level (*14*). Film bags of the desired dimensions are used to line each box. After the box is packed, the top of the bag is sealed by tying, heat sealing, or folding and taping. Thickness of the films may vary from 1 to 1½ mils.

The tolerance of pears to carbon dioxide is limited, and levels above 2 to 3 percent may cause core browning, cell dehydration, and death. Cavities occur in the dried tissue and the affected areas have a brown pithy appearance. The disorder may also extend into the fleshy part of the pear.

In the early use of polyethylene film for pear liners, the permeability to carbon dioxide was in the desired range and allowed from 1 to 3.5 percent to accumulate within the bag at 31° F., while the oxygen level varied from 13 to 18 percent (*15*). Later supplies of film were less permeable, and carbon dioxide concentrations of 5 to 10 percent were common. Consequently, the film liners required perforating or the use of a carbon dioxide absorbent within the packages. Liners with about 100 needlepoint perforations are commonly used commercially. They allow an accumulation of carbon dioxide within the package of about 1 to 2 percent and do not significantly change the moisture retentiveness of the film.

A recent development for holding the carbon dioxide at a low level involves its absorption by hydrated lime, packaged in envelopes, and used as a pad within the liners. The carbon dioxide is held at a low level, and at the same time benefits from low oxygen are obtained. The oxygen is generally below 12 percent, but does not reach levels low enough to cause injury (*18*).

When sealed polyethylene liners are used, be sure that the film is slit when the fruit is transferred from cold storage to warmer temperatures.

Pears are usually wrapped in Hartman wraps, which contain mineral oil to retard scald development and a copper compound to prevent spread of infection from a decaying fruit to adjacent ones. Recently some chemicals have been found that control Anjou scald more effectively than mineral oil. Ethoxyquin (Stop Scald) [4] is the most effective of these chemicals and may be applied to the fruit in a water dip or spray in the packing line or in paper wraps when the fruit is packed. Since the effectiveness of ethoxyquin is dependent on contact with the fruit, the treatment if applied in a dip or spray must not be followed with a water rinse.

[4] Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a warranty or an endorsement of the product by the U.S. Department of Agriculture to the exclusion of other products not mentioned.

Storage

When pears are to be stored for a long time, they should be cooled immediately after picking. If the fruit is to be consumed within a few weeks after harvest, immediate refrigeration is of less importance. For maximum storage life, pears should be held at about 30° F.

The length of time pears may be held in cold storage varies with the varieties. The storage life of each variety is fairly definite, and when pears are held beyond their normal storage life, they will not ripen properly upon removal. Even though they appear to be in good condition, the flesh will not soften, the skin "scalds" or turns brown, and breakdown may occur.

The storage life of pears may be affected by several factors, such as conditions under which the fruit was grown, maturity at time of harvest, time lapse before being thoroughly cooled, and temperature in storage. Thermocouples may be placed in fruit and air at selected locations in the cold-storage room while the fruit is being placed in storage. Accurate records can then be obtained during the cooling and storage periods and the information used for adjustment of refrigeration capacity, air circulation, and stacking patterns (*37, 47*). The length of time that pear varieties may be held in storage at 30° to 31° F. if picked at the proper maturity and stored promptly is given in table 8.

Bartlett pears for canning, when held for 15 to 30 days in cold storage, have better color and texture when canned than either those ripened without storage or those stored for longer periods. However, fruit harvested at proper maturity and cooled promptly gives a fairly good product even when stored for 2 months before canning (*12*).

Benefits from controlled-atmosphere storage of pears have been recognized for years (*2*), but this type of storage has not been extensively adopted commercially. This is probably because similar effects have been obtained with polyethylene liners. An atmosphere containing about 2 percent oxygen and 1 percent carbon dioxide is recommended for fruit stored at 30° to 31° F.

TABLE 8.—*Storage life of pear varieties held at 30° to 31° F. in boxes without and with polyethylene liners*

Variety	Maximum storage life in boxes—	
	Without liners	With sealed polyethylene liners
	Days	*Days*
Anjou	175–185	214–216
Bartlett	70– 85	107–126
Bosc	90–100	120–130
Comice	90–105	120–135
Hardy	75–140	.....
Kieffer	90–120	.....
Seckel	90–100	.....
Winter Nelis	175–230	.....

Shipping

Pears may go into immediate distribution and consumption after harvest, into cold storage in the production areas, or into storage at the terminal markets. The protective services for pears in transit are determined by the disposition to be made of the fruit upon arrival at its destination.

If the fruit is to go into immediate consumption, temperatures that permit some ripening in transit may be used. For early varieties such as Bartlett, Bosc, and Comice, shipped immediately after harvest, modified icing services should be used to provide temperatures of 45° to 55° F. for the first 5 to 6 days in transit (*43*). This will start the conditioning or preripening of pears, which is vital to the satisfactory marketing of the fruit. For transit periods of less than 6 days, the fruit may be treated with ethylene gas before or during shipment to hasten ripening (*46*). Pears shipped early in the season require longer to ripen than those shipped later.

The extent of ripening initiated in transit may be regulated by the transit temperature and correlated with the time required to ripen the fruit after it reaches its destination. Mechanically refrigerated cars and Ice Tempco cars, which use ice as a refrigerant and have thermostatically controlled fans, are well adapted for temperature control (*19, 20*).

Midseason and late pears are generally room or car precooled or are shipped from cold storage in the production areas. When shipped from cold storage in the fall and winter, ripening in transit may be initiated by the use of thermostatically controlled heaters. The recommended thermostat setting is 47.5° F. (*42, 44*). Because of the low temperatures that usually prevail in transit during late fall and winter, no significant warming of the fruit occurs from its own metabolism; therefore, heaters must be used. In shipments of pears from the Northwest, heaters installed at Chicago raised fruit temperatures to 50°–60° by the time of arrival in New York. Pears in these cars were then ripe enough for distribution 18 to 36 hours sooner than those in nonheated cars. Other tests indicated the feasibility of ripening pears by heating in rail fan cars after arrival at market (car fans operated by portable motors) and thus eliminating the extra handling required to move the fruit through ripening rooms.

If the pears are to be stored at terminal markets or transshipped overseas, they should be held in cold storage during transit. Fruit shipped immediately after harvest should be thoroughly precooled and shipped at temperatures as near 32° F. as feasible.

Ripening

For best dessert quality, most varieties of pears should be ripened at 60° to 70° F. and a relative humidity of 80 to 85 percent. Ripening temperatures higher than 70° are not desirable and may result in poorly flavored and textured pears or in losses from decay before softening.

The fastest ripening temperature for Bartlett pears is about 75° F., but ripening at 68° to 70° is only slightly slower. The fruit ripened at the lower temperature may be slightly better flavored. It also ripens to excellent quality at 60° to 68°, but for canning, the more rapid ripening may be desired because of the processing schedule. At a ripening temperature of about 85°, quality is sacrificed and the pears often become mealy, whereas at higher temperatures they may fail to ripen and often break down. Kieffer pears should be ripened at 60° to 65°.

Although pears may color and soften in storage, they cannot be assumed to have ripened normally unless they have developed full flavor and are very soft and juicy. The ability of pears to ripen depends on the storage temperature and the length of time they have been stored. Pears have a definite and limited storage life beyond which they will not ripen normally when removed to higher temperatures.

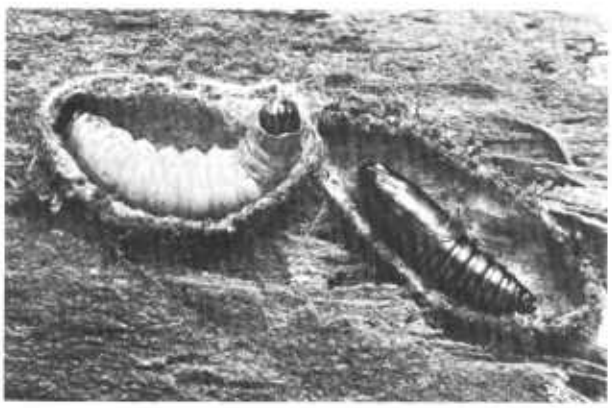
INSECTS OF PEARS

Pears cannot be grown profitably without adequate control of insect pests. It is essential to identify the insects in order to know what measures to take against them. For additional information on pear insects, see U.S. Department of Agriculture Handbook 306, Insect Pests of Deciduous Fruits in the West. Information on insecticides to be used, dosages, and timing of applications may be obtained from the county agricultural agent, State agricultural experiment station, or the U.S. Department of Agriculture.

Codling Moth

One of the most serious insect pests of pears is the codling moth (*Carpocapsa pomonella* (L.)). It must be controlled with a regular annual spray program, carefully timed and thoroughly applied. The insect is injurious only in the larval, or worm, stage. Young worms burrow into the fruit, either through the calyx end or in the side, usually at points where two fruits touch or where a leaf touches a fruit. After feeding beneath the skin for a few days, the worms go to the center of the fruit, where they feed on the seeds and core. When full grown, they tunnel to the surface and leave the fruit. Their presence is often evident from the brown frass that plugs the holes. Wormy fruit is of no value.

Codling moths winter as mature worms in cocoons under the loose bark of trees (fig. 14), in cracks, crevices, or bark wounds, and in litter on the ground. In the spring the worms pupate, and in a short time the adult moths (fig. 15) begin to appear, usually soon after the trees have bloomed. They continue to emerge for some weeks, the period extending through part of May and June. Moths are inconspicuous and are most active at twilight. Eggs are laid on fruit and leaves on evenings when the temperature is above 60° F. They hatch in 6 to 14 days, depending on the temperature, and the worms feed in the fruit for 3 weeks or longer. In the northern pear-growing areas there may be only one generation and a partial second, but in some areas with longer growing seasons, as on the Pacific coast, there may be as many as three generations.



BN–29830

FIGURE 14.—Codling moth larva and pupa in cocoons.

BN–29813

FIGURE 15.—Codling moth adult.

Oriental Fruit Moth

The oriental fruit moth (*Grapholitha molesta* (Busck)) occurs in most of the pear-growing districts of the United States. It attacks pear as well as other deciduous fruits. The pinkish-white worms burrow into the fruit in much the same way as those of the codling moth, and they cannot be readily differentiated. These pests hibernate in cocoons as full-grown worms, and there are several generations in a season. Ordinarily if the codling moth is controlled on pears, the oriental fruit moth will not cause much damage.

Pear Psylla

The pear psylla (*Psylla pyricola* Foerster) is a serious pest of pear, sometimes even more injurious than the codling moth. It has been in the Eastern States for over 100 years and appeared about 1939 in Washington. From there it spread to practically all pear-growing districts on the Pacific coast. Injury is limited to pears. Honeydew secreted by these insects runs down over the foliage and fruit, and a sooty fungus grows in it. This causes the skin of fruits to become blackened and scarred, and the foliage develops brown spots. Heavy infestations may cause partial defoliation of the trees, reducing vitality and preventing the formation of fruit buds. There is strong evidence that the psylla is associated with the development and spread of pear decline disease.

Pear psylla adults (fig. 16) have somewhat the appearance of miniature cicadas, with transparent wings sloping over the body. They are about one-tenth inch long and dark reddish brown. They can fly suddenly from where they are resting, giving the impression that they have jumped. Adults of the overwintering form are larger and darker than those of the summer form. They hibernate in crevices in the bark and on the ground. The adults may become active at any time when the temperature is above 40° F.

The elongated whitish or yellow eggs are deposited in March or sometimes even earlier in the small crevices about the buds, and they hatch in 10 to 30 days. After the foliage is out, many eggs are deposited on the leaves. The young nymphs migrate to the axil of the leaves or to the opening leaves themselves to feed. They are yellowish and flattened and soon cover themselves with the honeydew that they secrete. After going through four successively larger stages and becoming greenish, they reach the last, or "hard-shell," stage (fig. 17), from which they molt into adults. There may be three to five generations a year, the first one lasting about 45 days and the later ones about 30 days. Adequate control is often difficult to obtain, and any treatment must be carefully timed and thoroughly applied.

BN–29814

FIGURE 16.—Pear psylla adult.

Scale Insects

The San Jose scale (*Aspidiotus perniciosus* Comstock) may cause serious loss of pears if not controlled, for it infests not only the bark and foliage but also the fruit itself (fig. 18). It causes small reddish spots on fruit and foliage. Trees may be partially or entirely killed and the fruit becomes unmarketable. Actually this pest is not difficult to control and does little damage if recommended sprays are applied annually.

The scales are about one-twelfth inch in diameter, with yellow bodies protected by circular, grayish, scalelike coverings. Each mature female produces several hundred small, louselike, yellow crawlers, which migrate to new locations. These crawlers may be scattered about by wind, birds, or other means. Feeding is through a sucking beak. Growth is completed in about 6 weeks, the insect remaining in the same location. There are two or more generations a year.

In California, pears may be infested with the Italian pear scale (*Epidiaspis piricola* (Del Guercio)), which has habits and a superficial appearance similar to the San Jose scale. However, the soft bodies beneath the scales are reddish purple instead of yellow. Two other scale insects, the calico scale (*Lecanium cerasorum* Cockerell) and the European fruit lecanium (*Lecanium corni* Bouché), attack pears in California, and the latter may occasionally be found in the Northwest. They are one-eighth to three-eighths inch in diameter. They are convex, brown, and, in the case of the calico scale have irregular white marks. The adults live only on the twigs or limbs, but the flattened young usually feed on the leaves, where they produce large amounts of honeydew in which a black fungus grows. Control of these scales, if done during the dormant period, is not difficult.

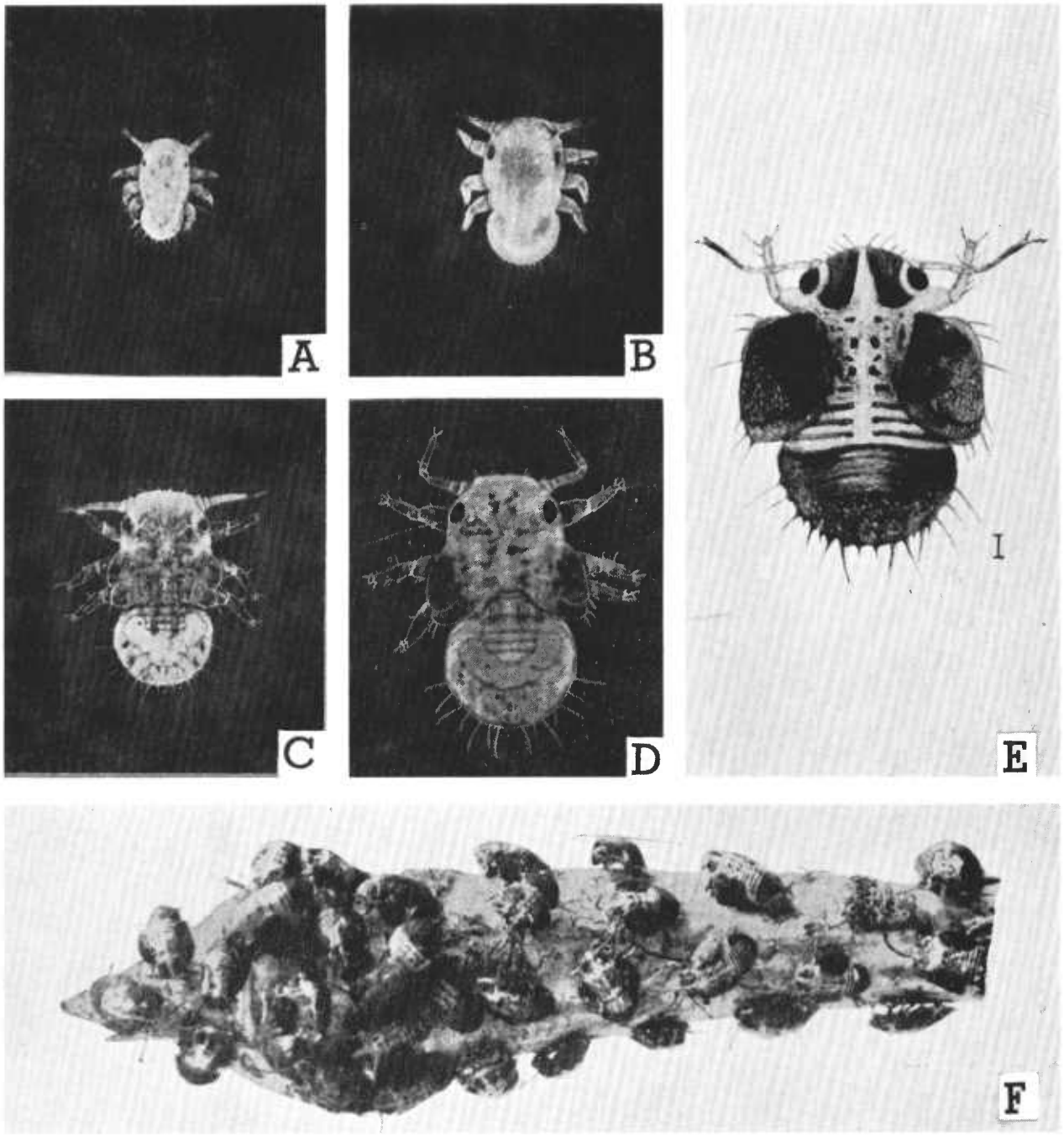


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FIGURE 17.—Pear psylla nymphs: *A–E*, Young stages; *F*, fifth, or "hard shell," stage on pear twig.

The cottony maple scale (*Pulvinaria innumerabilis* (Rathvon)) sometimes becomes a pest on Winter Nelis and Anjou, but is seldom seen on Bartlett. It is primarily a pest of maple. This scale is easily recognized by the cottony egg sac produced early in the summer. About 3,000 eggs are laid in this sac and they hatch during June and July. The young scales settle on the underside of leaves, and the partly grown females later migrate to the twigs, hibernating there and completing their growth in the spring. At this time they are brown,

BN-29821

FIGURE 18.—Pear infested with San Jose scale.

convex, and about one-eighth inch in diameter. After the egg sac is formed and the eggs are laid in it, the female dies. There is only one generation a year. Applications of dormant sprays, as for the San Jose scale, control this scale very well. Several other species of scale insects occasionally may be found on pears.

The grape mealybug (*Pseudococcus maritimus* (Ehrhorn)) is found throughout the Pacific Coast States and is an important pest of pear in California. These insects overwinter on the scaffold limbs in egg sacs as young crawlers. They migrate early in the spring and start feeding on the tender growth. When full grown, they are about one-fourth inch long, dark purple, and covered with a white powdery wax. Oviposition occurs late in June beneath the bark scales and at the base of new growth. This generation becomes adult by late summer. Injury results from honeydew dripping onto the fruit. Some of the mealybugs may also crawl into the calyx end, where their feeding breaks down the tissues. Control is more difficult than with the other scale insects on pear.

Orchard Mites

Orchard mites are important pests of pear, often doing great harm. Included are the European red mite (*Panonychus ulmi* (Koch)), the brown mite (*Bryobia rubrioculus* (Scheuten)) (fig. 19), the two-spotted spider mite (*Tetranychus urticae* (Koch)), and the McDaniel spider mite (*Tetranychus mcdanieli* McGregor). The first two winter in the egg stage on trees. The red eggs usually hatch before the blossoms open, and the young mites feed on the developing foliage. The European red mite adult is velvety red and very convex. The brown mite is dull red to greenish, flattened, and has longer legs. The brown mite feeds mostly at night, congregating on twigs and branches during the day.

The two spider mites winter as bright-yellow or orange adults under bark scales and in debris on the ground, migrating to the new foliage as soon as it develops and feeding first on the leaves nearest the trunk. When feeding, they are yellowish or greenish, often with two dark spots on the back. They spin considerable webbing.

Development of orchard mites is rapid in warm weather and there may be eight or more generations in a season. This makes control difficult and measures must be taken before serious injury occurs. The damage caused by

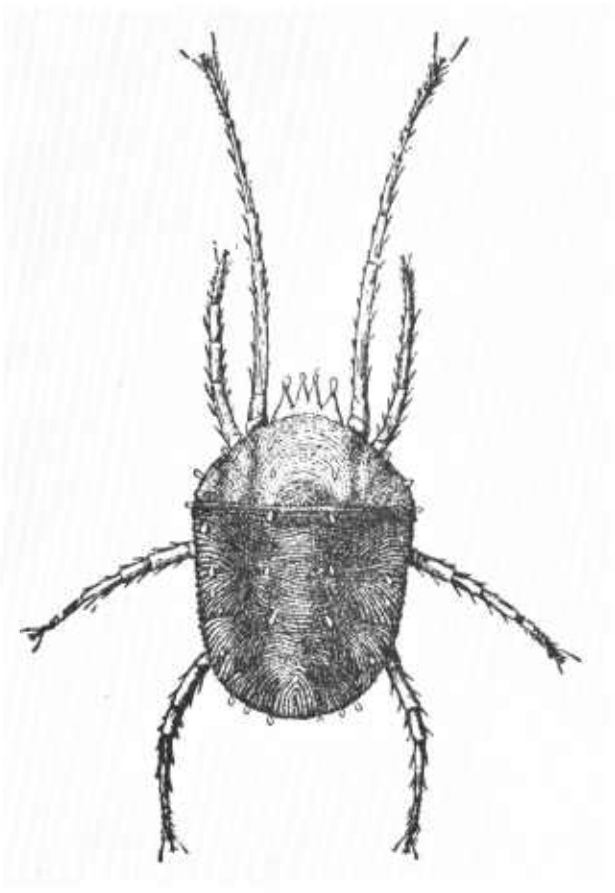

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FIGURE 19.—Brown mite adult.

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FIGURE 20.—Adults of pear leaf blister mite.

these mites is primarily to the foliage, which becomes bronzed or blackened; defoliation may occur, and serious interference with the normal development of the fruit results.

There are two other much smaller mites that live on pear—the pear leaf blister mite (*Eriophyes pyri* (Pagenstecher)) (fig. 20) and the pear rust mite (*Epitrimerus pyri* (Nalepa)). Neither can be seen easily without a hand lens. The pear leaf blister mites winter under bud scales, and the young of the new generation form characteristic blisters on the unfolding leaves in which the mites live. They also feed on the young fruit. Damage is usually severe only on young trees; on older trees the fruit may become russeted. Control may be obtained with fall or early spring spraying.

The pear rust mites winter behind leaf scales and in small crevices on twigs. They become active in the spring as the new growth develops, and feed on leaf surfaces and also on the fruit, which may become russeted. Sprays similar to those used for the pear leaf blister mite should give effective control.

Sucking Bugs

Several kinds of sucking bugs may attack pear fruit. Among these are lygus bugs (*Lygus* spp.) (fig. 21). They are small grayish or greenish bugs about one-fourth inch long. They may cause buds to drop in the spring or the fruit to become misshapen. Boxelder bugs (*Leptocoris trivittatus* (Say)) are larger and are black and red. They are more likely to attack the ripening fruit. The consperse stink bugs (*Euschistus conspersus* Uhler) are still larger, about one-half inch long, shield shaped, and gray brown. They are covered with small black dots. Local information should be obtained as to how to control these bugs.

BN-29818

FIGURE 21.—Lygus bug.

Thrips

The pear thrips (*Taeniothrips inconsequens* (Uzel)) is usually held in check by control measures used against other pests. These insects are about one twenty-fifth inch long, slim, and dark brown. The adults may be found in the opening buds, where they may prevent the blossoms from producing fruit. Later the white larvae feed on the developing pears and cause russeting. Another species, the bean thrips (*Caliothrips fasciatus* (Pergande)), is occasionally a pest of pear in some parts of California.

Sinuate Pear Tree Borer

In some of the Eastern States the sinuate pear tree borer (*Agrilus sinuatus* (Olivier)) attacks pear. The larvae burrow into the inner bark and sapwood. They are slender, whitish, and when full grown may be 1½ inches long. There is one brood a year, the adult beetles emerging in May and June. They are slender, purplish bronze, and about one-

third inch long. Occasionally entire plantings of young pears may be killed by this pest. Control consists chiefly in cutting out and destroying infested trees and branches during the winter. Insecticides applied for other pests in May and June will destroy many of the beetles.

Other Insects

The orange tortrix (*Argyrotaenia citrana* (Fernald)) sometimes occurs on pears, particularly in the coastal districts of California. The active, greenish, black-headed caterpillars of this leaf-roller moth feed on the surface of the fruit. There are several generations a year.

In the coastal areas of Oregon and Washington the syneta leaf beetle (*Syneta albida* LeConte) (fig. 22) attacks the young fruit (fig. 23) and foliage. These beetles are about one-fourth inch long and gray or yellowish. Both pests are normally controlled with sprays applied against the codling moth.

The pear midge (*Contarinia pyrivora* (Riley)), resembling a mosquito, is a small insect that occurs in the Eastern States. It emerges when the blossom buds begin to show color and deposits eggs in them. The eggs hatch in a few days, and the small whitish larvae feed in the developing ovaries, causing the young fruit to be deformed. When full grown, the larvae leave the fruit and enter the soil to spin cocoons, in which they remain until they transform to adults the following spring. Insecticides applied to the trees when the adults are emerging will control this pest effectively.

The pear-slug (*Caliroa cerasi* (L.)) (fig. 24) is slimy, olive green or black, and about one-half inch long when full grown. These slugs feed on the foliage. Other leaf feeders include the fruit-tree leaf roller (*Archips argyrospilus* (Walker)), a tentiform leaf miner (*Lithocolletis* sp.), the California pear-slug (*Pristiphora abbreviata* (Hartig)) (fig. 25), the spring cankerworm (*Paleacrita vernata* (Peck)), and the fall cankerworm (*Alsophila pometaria* (Harris)). All these leaf feeders are likely to be controlled with spray programs used against the codling moth and the pear psylla.

Aphids are occasionally found on pear, including the woolly pear aphid (*Eriosoma pyricola* Baker & Davidson), the melon aphid (*Aphis gossypii* Glover), the apple aphid (*Aphis pomi* DeGeer), the green peach aphid

BN-29817

FIGURE 22.—Syneta leaf beetle male and female.

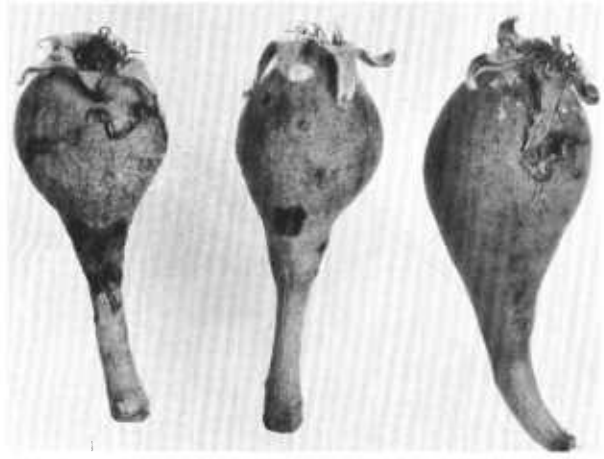

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FIGURE 23.—Young pears injured by syneta leaf beetle.

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FIGURE 24.—Pear-slug and its injury.

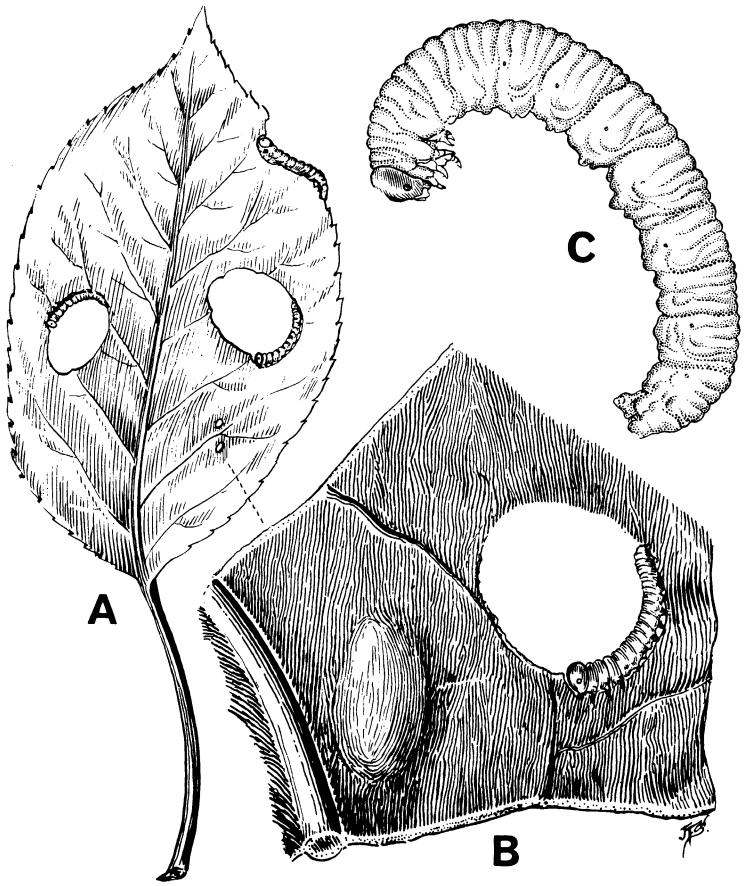

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FIGURE 25.—California pear-slug: *A*, Injury to leaf; *B*, egg in tissue and young larva feeding; *C*, full-grown larva.

(*Myzus persicae* (Sulzer)), and the bean aphid (*Aphis fabae* Scopoli). Control of aphids is usually not difficult.

The shot-hole borer (*Scolytus rugulosus* (Ratzeburg)) and sometimes another species, *Anisandrus pyri* (Peck), also may be found in pear trees, usually those in poor condition. The American plum borer (*Euzophera semifuneralis* (Walker)) and the Pacific flatheaded borer (*Chrysobothris mali* Horn) may also attack trees in poor condition. Keeping trees healthy will prevent most of these attacks.

The grubs of rain beetles (*Pleocoma* spp.) attack the roots of pear in Hood River County, Oreg., and occasionally elsewhere. They are whitish with brown heads and may be 2½ inches long when full grown. The buffalo treehopper (*Stictocephala bubalus* (F.)) and sometimes other species attack young pear trees in northern California and in the Northwest. Injury to the bark results when the females slit it to lay their eggs. Clean cultivation about the trees will usually prevent most of this injury.

PEAR DISEASES

Fire Blight

Fire blight is one of the most destructive pear diseases (fig. 26). Losses vary from blossom blight to destruction of large branches and entire trees. The extent of damage depends on such factors as varietal susceptibility, weather conditions, cultural practices, and control measures.

The disease was first recorded in the Hudson River Valley of New York in 1780. Nearly 100 years later the bacterium *Erwinia amylovora* (Burrill) Winslow et al. was found to be the causal agent.

BN-29828

FIGURE 26.—Fire blight of pear.

The disease usually appears first as a blossom blight, and later infection spreads to shoot growth and developing young fruits. The blossom-blight symptoms are confused in some areas with those caused by *Pseudomonas syringae* Van Hall (p. 39). As the bacteria invade the spurs and branches, the tissues turn dark green and become water soaked. Affected parts eventually turn brown, then black, and remain firmly attached to the tree. Under favorable conditions the bacteria move very rapidly. If left unchecked, they will advance from the blighted blossoms to the main branches, down the trunk, and into the roots. The bacteria may overwinter in cankers, which act as inoculum sources the following spring. Affected parts often produce droplets of clear, milky, or amber-colored exudate containing numerous bacteria, which are readily disseminated to susceptible tissue.

Insects disseminate the bacteria. Honey bees contaminate their mouth parts by feeding on oozing exudate from cankers and are often responsible for blossom infections during their search for nectar. Other insects may also cause blossom infections by accidental contact with bacterial exudate followed by later visitation to flowers.

Rain and windblown mist transfer bacteria from diseased to healthy plant parts. Blight epidemics often follow hail storms. The injury from hail apparently provides an entry point for the bacteria. Any means involving physical transfer of the bacteria to susceptible plant parts can also spread blight, provided other conditions are favorable. Control measures are designed to reduce inoculum and protect susceptible tissue.

Usually control necessitates removal of all infected spurs and branches as soon as they appear as well as affected areas on large branches, crotches, trunks, and roots during the dormant season. Cuts should be made well below the infected areas as soon as possible after they appear, regardless of the size of the wood. In these operations cutting tools should be disinfected between each cut to prevent possible transmission of the causal bacteria.

Corrosive sublimate and Reimer's solution have been used extensively as disinfectants but

are sometimes difficult to obtain. Streptomycin dips have been used in some areas also. Household chlorine bleaches containing 5 percent sodium hypochlorite diluted to one-tenth of the proprietary strength are more convenient, easy to obtain, and satisfactory. However, sodium hypochlorite is extremely corrosive to metal. Pruning tools are either dipped or wiped with a sponge that is saturated with the disinfectant between each cut. All tools treated with disinfectant should be thoroughly rinsed and dried when reuse is not anticipated within several hours. Infected wood must be removed from the orchard after pruning and burned promptly. *Under no circumstances should these prunings be shredded and left for mulch as is commonly practiced in many orchards.*

Helpful preventive measures include removal of all root suckers and succulent water sprouts that might become infected and carry the bacteria into the body of the tree. Cultural and pruning practices that discourage vigorous growth tend to reduce susceptibility to fire blight.

Application of chemicals in sprays or dusts has aided in blight control when used in combination with other control measures. Various forms of copper have been recommended for fire blight control (*22, 30, 45*). Bordeaux mixture has provided relief from the disease on pears. However, its value on apple for fire blight control has been less beneficial. All coppers, even the fixed forms, have been effective in certain localities but may russet some varieties. Dust formulations often have been less injurious than spray applications with the same chemicals. Anjou is especially sensitive to copper, and in recent years antibiotics have provided more satisfactory control on this variety.

Kienholz (*27*) demonstrated the effectiveness of streptomycin on the highly susceptible variety Forelle. However, fire blight must be severe or the crop of sufficient value to warrant costly antibiotic applications. Until safer and more economical chemicals become available, growers must rely primarily on other means for fire blight control.

Most of the commercially grown pear varieties are susceptible to fire blight. Nearly 80 species of the family Rosaceae are hosts of the disease. However, there are known sources of resistance in pears and apples, and plant breeders have developed new varieties with commercial potential. The widely grown Bartlett variety is one of the most susceptible and cannot be grown commercially in the warmer areas of the United States.

Fire blight is the most serious disease affecting pears and limits the production of the older high-quality varieties to the cooler growing areas of the Pacific coast, the higher elevations in the Mountain States, and small areas along the Great Lakes. Even in these areas much effort is necessary in the use of blossom sprays, prompt canker removal, good growing practices, and community cooperation to keep the disease in check.

Pseudomonas Blight

Another frequently troublesome bacterial disease of pears is caused by *Pseudomonas syringae* Van Hall (fig. 27). This disease has been known by many names, including blossom blast, lilac blight, false fire blight, and Pseudomonas blight. The last name is preferred because it distinguishes this disease from fire blight. These two diseases bear striking similarities, particularly in the blossom stages of infection. However, they can be readily separated by following the progress of symptoms beginning with the initial stage of infection.

Panagopoulos and Crosse (*38*) compared symptoms of the two diseases as follows:

BN-29820

FIGURE 27.—*Pseudomonas* canker on stem of young Bartlett tree.

"Pseudomonas blight begins as one or more discrete black lesions on the exterior surfaces of floral organs, e.g., sepals, receptacles, and pedicels. The lesions enlarge quickly, turning tissues black as they do so. Fire blight infections, on the other hand, originate through the nectariferous tissue in the calyx cup and spread rapidly into the receptacle and then via the pedicel into the spurs and branches. The infected tissues are at first dark green and water soaked, but after a few days they turn brown and take on a varnished appearance due to the spread of bacterial ooze over the surfaces."

Bacterial ooze has not been observed in association with infection by *P. syringae*. Calyx-cup infections are common and occur independent of blossom blast. Weather conditions were suggested as a predisposing factor of blossoms to the blight phase, and frost was shown to increase susceptibility to *P. syringae* (*39*). This would help to account for the sporadic appearance of the disease in many fruit-growing areas.

Symptoms of the disease in the twigs and larger wood of pear trees in California were described by Wilson (*53*). He noted that brownish streaks extended several inches through the cortex and outer phloem beyond the outwardly visible canker. Similar streaks are rare or entirely lacking when the wood is invaded by fire blight bacteria.

P. syringae has been associated with pear buds. However, the method or time of infection has not been established (*39*). In stone fruits, Dye (*11*) suggested that *P. syringae* enters the plant during the autumn and causes serious loss of young trees in the spring. Control of the disease in the Pacific Coast States has been based on the theory that most of the infection occurs during the fall and application of two bordeaux sprays is commonly recommended. The first spray should be applied when the leaves begin to fall and the second when most of the leaves are gone. These sprays have not been completely satisfactory and further testing is in progress to find more effective means of combating the disease.

Scab

Scab caused by *Venturia pyrina* (Aderh.) (fig. 28) is an important disease of pears in some areas of the United States, and when control measures are not practiced, losses are high. Its severity is dependent on environmental conditions and spore carryover from the previous year.

The general appearance of pear scab is similar to apple scab, the disease caused by the closely related fungus *Venturia inaequalis* (Cke.) Wint. apud Thuem. Leaves, fruits, and succulent young twigs are susceptible to attack. During seasons when rainfall is abundant at bloomtime, dark, velvety, or sooty spots begin to appear on the young fruits about petal fall. Fruits infected early usually drop, whereas those infected later remain on the tree and may be severely misshapen by harvesttime. Malformation of the fruit is caused by cessation of growth in the region attacked by the fungus while healthy tissue continues growth. Early infections may cover the entire side of the fruit, whereas later infections usually result in numerous small spots. The area in the center of a scab lesion may die and slough off, leaving a russeted area on the skin. It is common to find this corky area surrounded by sooty patches of active scab at the edge of the lesion.

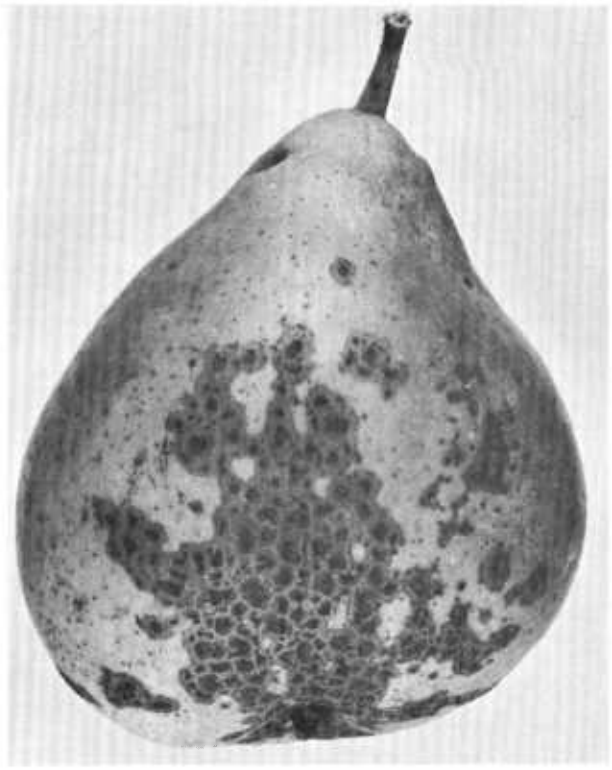

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FIGURE 28.—Pear scab.

Leaves often display dark velvety patches of the fungus similar to those found on the fruit. These spots generally are more prevalent on the lower leaf surface, although spots on the upper surface are also common. Leaf lesions are often found along the midrib, and as the affected part ceases growth, puckering and twisting commonly occur. Leaves infected

early in the season usually drop, and under epidemic conditions severe defoliation may seriously weaken the tree. The remaining infected leaves decrease their rate of food manufacture and contribute little to the buildup of reserves. Consequently, bud formation is decreased and the next year's crop may be adversely affected.

Infection of twigs may occur at any time during the growing season. New twig lesions appear as small blisters or pustules, which often slough off as the twig produces a corky underlayer. The remaining pustules are an important source of inoculum the following spring. Overwintering pustules rupture during moist weather in the spring and liberate spores (conidia), which are readily dispersed by rain and wind to cause new infections. The infection cycle may be repeated several times during the growing season, and fruits are susceptible until harvesttime. Fruits infected shortly before they are picked will appear normal when harvested, but may develop small pinpoint lesions during the storage period. Infection of the fruit after harvest has not been demonstrated.

Most features of pear scab are similar to those of apple scab. In addition to the production of conidia (summer spores), the fungus also produces perithecia on fallen leaves. The perithecia mature during the winter and early spring and develop ascospores, which are forcibly discharged and carried about by air currents during moist weather.

According to Kienholz and Childs (*28*), "continual moisture for periods of 5 to 48 hours is necessary for the spores to germinate and infect susceptible pear tissue. If the temperature during the rainy period is about 75° F., a spore may germinate and infect the plant within approximately 5 hours. At lower temperatures, moisture must persist for a correspondingly longer time so that at 40° F. a wet period of approximately 48 hours is required before infection occurs. After infection has taken place, an incubation period of 12 to 25 days is required for the fungus to become visible to the naked eye. That is why scab lesions often appear during periods that seem unfavorable for scab infection."

All the commonly grown commercial varieties of pear are susceptible to scab. Kienholz and Childs (*28*) stated: "Fruits of Anjou, Bartlett, Comice, Winter Nelis, Easter Beurre, Forelle, Seckel, and Flemish Beauty are often severely affected. Bosc fruits are very susceptible in the young stage, or until they shed their pubescence; afterwards they become highly resistant. Often a variety only lightly affected in one district may be the most seriously affected of all varieties in another." Langford and Keitt (*29*) showed that strains of the fungus exist and thus would account for such apparent differences in varietal susceptibility.

Control of this disease is complicated by the overwintering of the fungus on current-season twig growth, in contrast to the apple scab fungus, which overwinters exclusively on the fallen leaves. Plowing under the fallen pear leaves was recommended as a control measure in Australia, where it was demonstrated that leaves buried for 70 days were no longer capable of producing ascospores. Control measures in the current season are designed primarily to protect young fruits and leaves as they develop. Early-season efforts are imperative to successful pear scab control. Many control schedules recommend the application of lime sulfur in the dormant period just as buds begin to swell. Lime sulfur, ferbam, and dodine are fungicides most commonly recommended during the bloom period and into the growing season. Dodine has been more effective and less injurious than other materials after the dormant spray.

Root Disorders

Various root diseases are found in most pear-growing regions of the United States and have been referred to as collar rot, crown rot, and root rot. The primary pathogens are several species of the fungus *Phytophthora*. Collar rot on pear trees was reported in British Columbia by McIntosh (*31*). He showed that *P. cactorum* (Leb. & Cohn) Schroet. on pear trees was the causal agent. More recently McIntosh (*33*) showed that two other species of *Phytophthora* were capable of infecting pear rootlets. Cameron (*7*) demonstrated that *P. cinnamomi* Rands was pathogenic on pear roots.

Trees infected by species of *Phytophthora* are characterized by generally poor growth. Those attacked by *P. cactorum* may eventually die because of a girdling of the trunk at or below the ground line. *P. cinnamomi* kills young feeder rootlets, but is not pathogenic on the larger roots and crown tissue. McIntosh (*32*) stated that nursery stock infected with *Phytophthora* resulted in a high percentage of unthrifty trees. Some trees produced little or no growth for several seasons after planting.

Although differences in varietal susceptibility have been observed, little information on the subject is available. Cameron (*7*) reported a lower percentage of infection in Old Home, Old Home × Farmingdale seedlings,

and *Pyrus calleryana* Decne. than in Winter Nelis and Bartlett. Until more research on varietal susceptibility is completed, control measures are dependent on means other than resistance.

Collar rot losses can be reduced if the disease is detected before damage to the cambium occurs. Infected tissue should be exposed to the air and allowed to dry thoroughly. However, this practice would be of no value where young rootlets are rotted by *P. cinnamomi.* The area adjacent to the trunk should be kept free of weeds and debris so that rapid drying will occur after rain or irrigation. Proper irrigation is of prime importance and may vary considerably under localized conditions.

The fungus is especially sensitive to copper, and painting or spraying the trunks at the ground line with copper fungicides has been helpful. Applications should not be repeated at frequent intervals because copper toxicity may develop. In Washington, where collar rot has recently become a severe problem, it is recommended that the soil be removed from around the trunk and replaced with pumice. To help prevent root and crown disorders, shallow planting is desirable. Successful control of collar rot depends primarily on the maintenance of well-aerated soil and prevention of free-water accumulation.

Armillaria root rot, also known as oak root fungus, crown rot, and shoestring root rot, is caused by the fungus *Armillaria mellea* Vahl ex Fr. The disease is not considered an economic problem generally, but in some localities it is troublesome. Pear trees of all ages are susceptible to attack by the fungus. Masses of fungus mycelium known as rhizomorphs penetrate the root of the host plant. These structures attach themselves to the host root and apparently enter through a combination of chemical and mechanical means. The rhizomorphs grow rapidly throughout the root between the bark and the wood, forming a white fingerlike growth. Large areas of the root are killed by the action of the fungus, and as the crown becomes girdled the tree declines and eventually dies.

The fungus can live saprophytically in the soil or may parasitize a wide range of host plants. Resistance to *Armillaria* is known, but it is not a commercial pear-growing practice for control of this disease. Soil fumigation with chloropicrin or carbon disulfide has been successful on light soils, but only provides partial control on heavier soil types. When practical, newly cleared forest land should be avoided for new pear plantings if *Armillaria* is a problem.

Powdery Mildew

Powdery mildew of pears is caused by *Podosphaera leucotricha* (Ell. & Ev.) Salm. Although this fungus is more common on apple, it is readily spread from this host to pears. The fungus commonly overwinters on infected apple buds and is disseminated to pears in the spring. In Oregon the fungus is capable of overwintering on infected buds of pear seedlings and invades the new shoots as they develop. Infected tissue becomes covered with a white fluffy mycelial growth, on which conidia (spores) are borne. These spores can infect tender young fruits, leaves, and shoots. The disease cycle may be repeated every 5 to 7 days under ideal environmental conditions. Symptoms on pears are identical to those on apples, but often mycelial growth and spore production are more limited. Buds weakened by powdery mildew are more susceptible to winter damage and are often severely injured during cold weather. Early infection of the young fruit may cause serious russeting and render it unsalable by harvesttime.

Control of powdery mildew is usually achieved by several fungicide applications beginning at the prepink stage. Lime sulfur and various other sulfur compounds are sometimes used for powdery mildew control on pears. However, Kienholz (*25*) demonstrated that wettable sulfur fungicides reduced fruit set of Anjou when applied from the pink stage through three or four cover sprays.

Leaf Spot Diseases

Two leaf spot diseases of pear are found throughout the United States, but more frequently are troublesome in areas east of the Mississippi River. Early leaf spot is caused by the fungus *Fabraea maculata* Atk., and appears in early spring (usually April). The spots are mostly circular in outline and dark brown to nearly black with purplish margins. Spotted leaves turn yellow and drop, often causing profuse bloom in early fall. The fruits of some varieties, such as Garber, may develop black cankers and cracks after infection.

Late leaf spot is caused by *Cercospora minima* Tracy & Earle. Symptoms usually appear in August as indefinite, angular, brown to grayish spots without definite outline and follow the areas between major veins. Severe infection of pear trees by *C. minima* may cause defoliation.

Ferbam sprays control early blight and should be applied when the spots begin to appear in April, followed by one or two sprays

at 3-week intervals. Late leaf spot may be controlled with a similar spray program, with application of the first spray in late July. Copper sprays should be used only in severe infection because of risk of fruit russet. Sanitation measures, such as plowing under or removing fallen leaves, help to reduce the incidence of these two leaf spot diseases.

Virus Diseases

Virus diseases are a major threat to the pear industry. Losses may take various forms. The overall effects are reduced tree vigor and fruit quality, lower yields, and even death of trees. Virus diseases of pear have not been so intensively investigated as those of stone fruits or apples.

Until recently the only virus disease of major importance on pears was stony pit, described by Kienholz (*24*). Posnette (*41*) listed five groups of pear virus symptoms in addition to those of stony pit. Pear "blister canker" was shown by Cropley (*9*) to be caused by a virus. Millecan and others (*36*) reported a wood-pitting disorder in pear trees and showed it to be of virus origin. Further transmission tests will most likely reveal other virus diseases of pear.

Several accounts of virus transmission in pear trees, exclusive of pear decline, by means other than graft union of diseased to healthy tissue are reported (*8, 40*). Observation of the spread of virus diseases in pear orchards often suggests transmission by vectors, such as insects or nematodes, but this has not been confirmed by experimental evidence. Growers should be aware of the virus diseases known to affect pears and the steps necessary to prevent their spread to healthy trees. The following description of pear virus diseases should be helpful in recognizing these problems as they exist in the orchard.

Stony Pit

Stony pit is characterized by stony tissue in the pear fruit, usually at the base of dimples and depressions. Severely affected fruits are misshapen, malformed, and unsalable. Bosc is the most severely affected, but symptoms occur on other varieties.

In Oregon stony pit symptoms have not been observed on Bartlett fruits, even where this variety has been topworked on affected Bosc. In California severe symptoms have been seen on fruits of a few Bartlett trees, indicating the possible existence of a virus strain capable of infecting this variety.

The tissue develops early in the growth of pear fruits. Dark-green areas are formed just beneath the peel 10 days to a month after petal fall. Rapid development of surrounding normal tissue results in depressions or pits. When several of these occur together, pear fruits become drastically distorted. Cutting into the pitted area reveals stony masses of grit cells. The severity of stony pit symptoms is variable among fruits on an affected tree and among trees of a single variety. Symptoms vary in severity from one year to the next. Trees with severe symptoms one year may show moderate symptoms in another year, but the relationship of symptoms from tree to tree will usually be in the same proportion. Symptoms of stony pit should not be confused with those caused by the tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)), cork spot, or boron deficiency.

Kienholz (*26*) described chlorotic flecking, leaf banding, and rough bark symptoms, which he associated with stony pit. Subsequent work has indicated that these symptoms are caused by other viruses occurring concurrently with the stony pit virus.

Control of this disease consists primarily of propagation from stony pit-free trees. No methods for curing affected trees in the orchard or for reducing the severity of fruit symptoms are known. Some growers have followed the practice of topworking affected Bosc to Bartlett or other unaffected varieties. Some evidence indicates spread from tree to tree, but this needs to be substantiated.

Pear Bark Measles

This disease is characterized by the formation of blisters followed by longitudinal splitting and cracking of the bark on the stems of young trees. Necrosis of the underlying phloem tissue accompanies development of this virus disease and may eventually cause death of the tree. Cordy and MacSwan (*8*) suggested that it may be seed transmissible.

Red Leaf (Curl)

"Curl" is the name associated with a red leaf condition of pear trees, which appears in late summer and is not associated with pear decline. The disease is reported from California (*35*) and, although not yet proved, this disorder suggests a virus as the causal agent. Affected trees have undulated reddish-purple leaves, the tips of which typically curl under and toward the midrib. They may be shaken from the trees easier than those from healthy trees, but not so easy as those affected with

pear decline. Red leaf or curl affects all varieties of pear trees and shows some differential in symptom severity between trees and different rootstocks. The number of affected trees is still small, but the disorder is regarded with much concern.

Premature reddening of pear leaves may also result from other causes, such as girdling by rodents or various other root injuries.

Leaf Mosaics

Posnette (*41*) listed leaf mosaic, vein yellows, and red mottle as virus diseases of pear. Quince veinbanding and hawthorn ring pattern occur as latent viruses of pear. Symptoms of pear leaf mosaic are irregular, chlorotic, greenish-yellow areas on dark-green healthy tissue. These areas are usually associated with the veins, but are distinguishable from symptoms of the veinbanding virus, in which yellowing is confined to the area adjacent to the veins. Chlorosis caused by veinbanding is usually found as narrow, yellow, continuous bands along smaller veins, and is generally more severe in young rather than in mature trees.

There is no practical means of curing virus-infected pear trees in the orchard. However, it is possible to obtain virus-free varieties by special heat treatment. Programs to supply nurseries with virus-free stock are not yet completely developed, but such material will eventually become available. Economical operation of pear orchards in the future may well depend on the planting and maintenance of trees that are free of the major virus diseases.

Pear Decline[5]

Pear decline is caused by a virus spread by the pear psylla (*Psylla pyricola* Foerster) (*6, 23, 48, 50*). The disease was recognized as early as 1946 in central Washington and was reported in 1948 in British Columbia (*49*). During the next 10 years pear decline spread to all the commercial growing areas of Washington. It was recognized and reported in Oregon in 1957 and appeared in California in 1959. In all these areas it has spread rapidly, with the loss of many thousands of trees.

The symptoms of pear decline are similar to those of the moria disease of pears described from Italy, and the two diseases are considered identical (*49*). The causal virus was probably brought into the United States on symptomless, nonsensitive pear stocks, where it had existed without symptom expression for a long time in the absence of an insect vector. The pear psylla became established in the early 1940's in British Columbia, from where it spread into the United States. Pear decline has spread almost coincident with the spread of the pear psylla in the Western United States. Pear decline currently has not been recognized anywhere in the United States except in Washington, Oregon, and California.

Symptoms of pear decline are generally of two types: (1) Quick wilting and death of trees, in some cases within a week, and (2) slow decline, characterized by cessation of normal growth shortly after spring foliation, failure of fruit set or failure of fruit to mature normally, progressive weakening of trees, and often death after one to several years. Both types are associated with sieve-tube necrosis just above the bud union (*4*). The rapid death type was spectacular where the disease invaded new areas, especially during the height of the growing season in the hot interior valleys of California.

Many otherwise normal trees in infected areas develop striking preseason autumnal red and yellow coloration. These trees are regarded to be in incipient stages of infection and show decline symptoms the following year. Symptoms of pear decline are somewhat nondescriptive and hence are easily confused with those resulting from other causes that interfere with normal growth.

Infected trees generally are growing on the so-called oriental pear rootstocks—*Pyrus serotina* and *P. ussuriensis*. Some diseased trees have been found on *P. calleryana* and to a less extent on *P. communis*. Orchards on domestic (*P. communis*), particularly Bartlett, seedlings grown from seed collected in orchards where Bartlett was pollinated with Anjou have not been affected. Trees on Old Home, a fire blight-resistant variety used as a rootstock or as a body stock and planted deep to allow its own rooting, have also not been affected. Some affected trees have occurred on French rootstock, which supposedly is *P. communis*. Such seed lots may be mixed or could be hybrids with pear decline-sensitive parents. *P. serotina* and *P. ussuriensis* were widely used after World War I because of their vigor and blight resistance, but fortunately were nearly discontinued in the early 1940's after hard end was shown to be associated with *P. serotina*.

The use of nonsensitive rootstocks, such as seedlings of Bartlett pollinated by Anjou, is currently the best recommendation for control. Affected trees do not recover sufficiently to produce economic crops and should be replaced with trees on tolerant rootstocks. The pear psylla is a prodigious feeder on pear species,

[5] Prepared by L. C. Cochran, Crops Research Division, Agricultural Research Service.

and therefore the causal virus of pear decline will probably become universal in susceptible species in infected areas.

Physiological Disorders

Hard End

Hard end or black end makes fruit hard, rounded, or often black over the blossom end as it approaches maturity (fig. 29). This disorder occurs almost exclusively on trees propagated on oriental stock. It is generally attributed to unfavorable water relationship within the plants and fruits. Ackley (*1*) found that the water-supplying power of the Japanese rootstock is not so great as that of the French stock. If this is the case, an intense competition for water may exist among the organs of the Japanese rooted trees during hot periods when water loss is excessive.

Hard end has ceased to be a serious problem in western pear culture, since most of the trees on susceptible stocks have succumbed to pear decline. The disorder may be largely avoided by using the proper rootstocks (see table 6).

Cork Spot of Anjou

In certain instances Anjou pears develop a serious fruit disorder known as cork spot. Affected fruits develop internal necrotic spots, which are often associated with external sunken areas, giving the fruit a bumpy appearance (fig. 30). Such pears are unmarketable. Frequently insufficient symptoms on the surface prevent detection when the fruit is graded.

Cork spot is more serious when trees are propagated on oriental roots. Also, relatively light crops of large fruits are more prone to develop the disorder. In this respect it is similar to bitter pit in apples. During periods of moisture stress (hot days) the leaves apparently pull moisture from the fruit, resulting in the death of cells in the flesh and the formation of cork spots. Cork spot can be largely avoided by the use of French rootstocks and the employment of cultural practices that will be conducive to a heavy set of fruit.

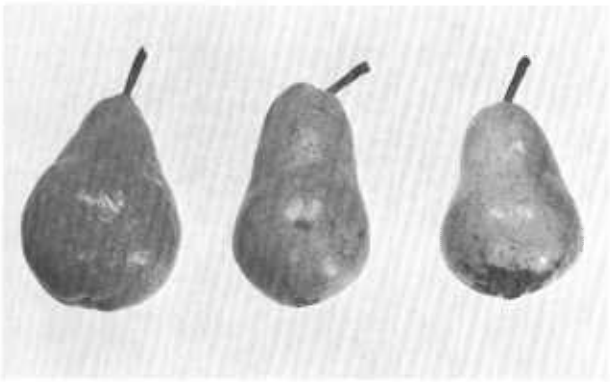

FIGURE 29.—Bartlett pears showing two stages of hard end disorder: Left, normal; center, hard end; right, black end. (After Ackley (*1*).)

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FIGURE 30.—Cork spot of Anjou.

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